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THE FILTRATION OF WATER IN GERMANY.

BY M. L. HOLMAN, MEMBER OF ENGINEERS' CLUB OF ST. LOUIS.

[Read before the Club, May 18, 1898.*]

IN the following paper I shall describe German practice in filtration as it appears from an engineering standpoint, divested of all scientific superfluities, and shall give only those features which pertain directly to construction and operation.

The work in Germany which may be taken as typical of plain or natural sand filtration is that at Hamburg. The National Board of Health of the German Empire requires that filtered water shall contain less than 100 bacteria per cubic centimeter. This is an arbitrary standard first selected as the result of laboratory experiments, and then adopted as the official standard, after considerable practical experience in the larger cities and works of Germany.

The Hamburg filter basins are eighteen in number, and are each about 70 meters wide and about 100 meters long. They are rectangular in plan, with rounded corners. The sides of the basins slope at an angle of about 45°, and the floor and slope are formed in the manner usual in reservoir construction. The floors and the inner slopes are covered with puddle, which is protected by concrete and brick. The brick construction covers the floor and about half of the slope. The upper half of the slope is covered by a very smooth concrete, similar to what we have here in our granitoid pavements. At appropriate places in the bottom of the reser-

*Manuscript received June 9, 1898.—Secretary, Ass'n of Eng. Socs.

voir channels are formed in the brick for the purpose of leading off the filtered water. For a portion of their depth these channels are countersunk in the bottom of the basin, and are afterwards completed by laying brick loosely along the sides and tiling over the top. After these channels are completed the filter is built up to the top of the channels, beginning with broken stone, following with gravel, then with fine gravel, then with coarse sand, and over all is placed the working layer of sand, one meter thick and of a fineness depending somewhat upon the character of the water, although the question of fineness has not been given much study in Germany. You will see that a meter in depth of sand is the working body of the filter, the materials under that simply supporting the sand. The entire depth, sand and all, acts solely as a support for the blanket or film of bacterial jelly or slime, which naturally forms while the raw or foul water rests upon the filter. Of course, in building up the filter bed great care must be taken to fill the smallest crevices, so that the entire body is sound and uniform, and so that an even surface of sand is left on the top of the filter. The filter is then set to work at its normal rate. This rate varies in different cities, the maximum rate in any city being 125 millimeters per hour, while at Hamburg the maximum rate is 100 millimeters per hour; that is, the velocity with which the water passes through the sand.

Now it is found that after the filter bed has been at work, for a time varying from three days to a week or more, depending upon circumstances that are not thoroughly understood, there appears upon the surface of this sand, and in the upper portion of it, a veil or film of slime. As soon as the filter is put at work the output is examined. This examination goes on for a time, and when it is found that the output contains less than 100 bacteria per cubic centimeter the filtered water is used. Until then it is wasted. The work of the filter then goes on, examinations being made daily and recorded; and as soon as the output shows an increase up to about 75 bacteria per cubic centimeter the filter is put out of work and cleaned. At times the filter has to be cleaned because the output becomes too small, although the head on the filter has not reached the maximum, and athough the output of filtered water is still within the required limit of purity. The maximum head allowed for forcing the water through the filter is 0.6 meter. The total depth of water above the sand is 1.1 meters. Each separate filter is examined and kept track of very carefully. At times the filter will suddenly begin to discharge water containing a surplus of bacteria. Those engaged in the practical operation of the

works in Germany and in the practical study of them, and upon whom devolves the care of furnishing the city with filtered water, are as yet unable to account for this action. They attribute the entire operation of the filter and of the bacterial purification to the change taking place in the water passing through the slime or blanket which forms on the surface. The change, as near as I could ascertain from them, is a natural process, the slime being a place where the bacteria stop by preference, and where some of them die, some of them are eaten up, some stay because they like it better than anywhere else; the idea being that the operation is confined exclusively to the slime, and is not in anywise chemical in its action. The engineers in charge of the filters of Hamburg, Bremen and Worms knew nothing of the "nitrifying action" talked of and written of in this country, their idea being that the action of the filter excludes the bacteria only.

When the filter needs cleaning the water is drained off and an examination is made of the upper surface of the sand. It is then found that the slime formation has penetrated to different depths in the sand, varying with the time of the year and other conditions. The cleaning is carried down to twice the depth to which the sand shows contamination, varying from a half an inch to a good stiff spading, according to the time of the year and the conditions under which the filter is worked. The labor of cleaning the filter is exceedingly heavy. It is accomplished by means of small railroad cars on a narrow-gauge track. After the filter has been cleaned it is again set to work, and this process is repeated until only about 16 inches of sand are left, when the filter is again restored to its original condition.

Now the cleaning of a filter in winter (and I speak only of open filter basins such as they have at Hamburg) is a complicated process, both expensive and inefficient, and is accomplished by the use of a machine which I will try to describe.

A cut is made through the ice on the side of the filter, and the machine shown in Figs. 1 and 2 is inserted under the ice. This machine is dragged along, the float being held against the ice by its buoyancy, and the bag dragging on the sand. That operation scrapes off a small amount of the sand and slime, which accumulates in the bag. When the bag reaches the other side of the filter it is drawn up to the bank, and reversed by means of a rope. The process goes on, the machine traveling back and forth across the filter, until all the matter to be removed has been scraped into piles at the sides of the filter. About two scrapings under the ice are about all that can be given to a filter. This scraping reduces the

output of the filter about one-half. The dragging action of the canvas bag seems to plaster the surface of the sand and tighten it up so that afterwards the water finds increased resistance to its passage through the bed.

The sand that is removed is cleaned by a machine, Figs. 3 and 4, which requires 20 cubic meters of filtered water to clean one cubic meter of sand. The sand is fed into a trough with a stream of water. From the bottom of this trough arises a pipe which is fed by an ejector nozzle running filtered water under a very high pressure; this nozzle throws the sand to the top, where it is sent back or travels over into a trough and runs down into a second truncated pyramid with a similar ejector. This process is continued until the sand has had a thorough washing, and is then so clean that a handful of it thrown into filtered water will not produce the slightest cloudiness in the water.

The building and loading, or preparing, of the filters is very expensive, and the operation and cleaning of the beds are also exceedingly expensive, notwithstanding the cheapness of labor in Germany. With us these operations would of course be still more expensive.

The Bremen filters are very similar to those at Hamburg, with the exception that they are built in covered vaults. The only difference in the operation is a modification in the cleaning as practiced in winter. Of course, with the filter in a covered vault the workmen can get at the top of the sand and can lay their small tracks running narrow-gauge cars, soon getting the sand out for the washing machines.

The sand-cleaning machine used at Berlin is somewhat different from those in Hamburg. At Berlin the sand is run through a long cylinder. It is fed to the top of the cylinder with a spout and comes out of the lower end of the cylinder, filtered water having been fed through at the same time. The sand runs off in a series of troughs, and is shoveled out of the last trough by hand.

The most difficult water in the German Empire to filter or handle is that of Bremen. The river is very small and very foul, and it has been found necessary to adopt a system of double filtration. The filters are similar to those at Hamburg, with the sole exception of the sides, which are vertical at Bremen instead of sloping, as at Hamburg. The study of the film which forms on the sand has been carried further at Bremen than at any other filter plant. It was found that with one filtering of the water it was impracticable to obtain the standard required by the National Health authorities, and it was then decided to try whether further purifica-

tion could be obtained by again passing the filtered water through a second film, the two filter beds working "in series," to use a term borrowed from the electric fraternity. The raw water is introduced on filter No. 1, passes through and is syphoned over, as raw water, to filter No. 2. It is found that passing the water from the first filter through the film on filter No. 2 improves the character of the water to an extent that warrants its use. A matter of peculiar interest, resulting from the examination of the Bremen filters, is that the slime, film or "blanket," which does the work, cannot be formed from the partially filtered water which had gone through filter No. 1; so that, in order to prepare the filters for work after filter No. 2 has been cleaned, it must be used a short time as a primary filter, in order to accumulate the necessary slime on top of the sand. It is then put in as the secondary filter, and runs for a considerable time. This fact, as practically demonstrated at Bremen, was conclusive evidence to me that the entire process of filtration, as practiced in Germany, depends simply upon the securing of the film on the top of the sand, and its scientific and skillful handling. This position is that of the engineers in charge of the works at Berlin, at Bremen and at Hamburg.

I also examined carefully the Fischer sand-plate filter in Worms. The city of Worms having reached the capacity of its filter plant, which was a natural sand filter similar to the later one built in Berlin, it became necessary to increase that capacity. The engineers in charge of the filtering works, and the scientific men having that matter in charge, being of the opinion that the filtration process, so far as bacteria was concerned, was due entirely to the film, set to work to devise a means of supporting this film more cheaply than by a horizontal layer of sand. Their studies resulted in the production of an artificial hollow stone block, called an "element." This element, as usually built, is a rectangular vertical box one meter square. The necessary thickness of sand was found, by preliminary experiment, to be 2½ to 3 inches. At Worms these elements were placed in one of the vaults where the plain sand filter had been used. The first experiment proving successful, the number of units was afterward increased, increasing eight-fold their capacity for aggregate output of filtered water per acre; that is, with the same area eight times the former amount of filtered water could be furnished. The new Wormser filter is worked exactly the same as a sand filter, the raw water percolating through the elements, and the filtered water runs off through the clear water pipe. When the filter is first put to work the water is allowed to run to waste, as in the plain sand filter, until the output

shows the requisite purity of less than 100 bacteria per cubic centimeter. As soon as this standard is reached the filter is put to regular work, the blanket having formed over the working surface of the elements. The output of the filter is examined, the same as with the plain sand filter. The head is the same and the average velocity through the stone the same. When the output falls below the requirements, or when the number of bacteria begins to exceed the limit, the filter is cleaned, not, as in the sand filter, by removing the sand, but by reversing the current of filtered water back through the element; that is, the slime formation is driven back and the porosity of the stone is restored by a counterflow of filtered water. When this is skillfully done the film is not totally destroyed, and the filter, after cleaning, is ready to proceed at once with the work of furnishing filtered water of the required standard. This system has been in use successfully in Worms for some years.

The waters treated in the plants which I have described do not carry a very large amount of sediment. The sediment-carrying waters on the continent are mostly in Russia and a part of Austria. Attempts have been made to filter those waters, especially at Warsaw, in Poland, on the English or plain sand system. But while the bacterial film or blanket is formed, and while the output, from a bacteriological standpoint, is good, the sand filter has not succeeded in stopping the finely divided inorganic sediment. At several places in Germany a chemical treatment is used for freeing the water from inorganic sediment and from iron. For some reason, which I could not ascertain, the National Health authorities of Germany forbid the use of aluminum sulphate in filtration. I understand, however, that their objection is that the treatment renders the water acid. The authorities do, however, allow treatment of water by means of an iron solution. This iron solution, used preliminary to filtering it, forms a coagulant, which, as with sulphate of aluminum, is strained out of the water afterwards by filtration. Where a coagulant is used, subsequent filtration is simply a straining. The film or blanket, which forms in the plain sand filter, is not formed, and is not sought for. In filtration after coagulation the object is simply to use a sieve fine enough to keep out the coagulated matter and the iron which has been introduced into the water, or which may have been in the water before it was treated.

All of the engineers with whom I talked on this matter, and they all spoke English with the same difficulty that I spoke German, agreed that in the treatment of water containing the amount

of sediment which the waters of some rivers of Russia or those of the Mississippi River contain, a preliminary treatment would be necessary, and that it was exceedingly doubtful whether the film on the surface of the sand would do the bacteriological work, the reason being that the preliminary sedimentation would deprive the water of its stock of bacteria, depleting it to such an extent that the bacteria left would not suffice to form the film. This was indicated by the result at Bremen, where, although the partially filtered water contains more bacteria than allowed by the health authorities, the film necessary for successful filtration is not formed.

The amount of sediment in our water here, when I explained it to them, was of course beyond their comprehension. While they were too polite to contradict me, I perceived that they doubted my assertions. They were strongly of the opinion that preliminary sedimentation and coagulation would be necessary. One thing, among others, I learned, and that is that there is no hole so small that the bacilli can not get through it.

DISCUSSION.

Prof. Johnson.—Is the iron process mentioned the Anderson?

Mr. Holman.—No. It consists in the introduction of iron chloride into the water. The problem is to bring the cost of the manufacture of the chloride within the financial reach of the works.

Prof. Johnson.—Is the action of the chloride similar to that of aluminum?

Mr. Holman.—No. The iron chloride forms iron hydrate in the water, while aluminum forms aluminum hydrate.

Prof. Johnson.—Does not coagulation take place in the Anderson process?

Mr. Holman.—Yes.

Mr. Moore.—Are mechanical filters used in Germany?

Mr. Holman.—No. Their use is forbidden, as is also that of the individual house filter. Up to within a very short time the Germans have failed to discover a house filter giving sufficient protection against bacteria. Even the Pasteur failed to meet their requirements. The filtration plants are built and operated by the municipal authorities, under the supervision of the National Health authorities of the empire. Experiments have, however, been made with appliances imported from the United States, in connection with the Worms element, which has passed the necessary inspection and fulfilled all the requirements of the health authorities.

As a house filter the Worms element, when properly handled, is as much proof against bacteria as the municipal filter.

Mr. Hermann.—Can you explain briefly the operation of the mechanical filter?

Mr. Holman.—The mechanical filter, as generally used in this country, consists of a shell or tank, in which a considerable depth of sand is placed. At the bottom is a fine strainer, with tubes for drawing off the filtered water. On top of the sand is introduced the raw water and a proportionate amount of aluminum sulphate or alum, varying from one grain to the gallon up or down, as the case requires. This coagulant forms in the water a precipitate, which is caught on the surface of the sand. When the sand becomes so clogged with the precipitate that the output is materially diminished, the filter is washed by reversing the direction of the current of water through it. In this country raw water is sometimes used for washing. This throws the raw water on the clean side of the filter, and of course leaves the sand, after washing, with whatever bacteria may have been carried to it by the raw water. The filter is then put to work and allowed to run until the water runs clear, without reference to its bacteriological condition. In the tanks are placed revolving rakes, worked by machinery, in the sand during washing. The mechanical filter, as used here, acts simply as a strainer. The bacteriological results have not been carefully investigated as yet. The mere fact that various filter companies, in reporting the operations of their filters, state the percentage of bacteria removed, does not prove sufficient knowledge of the subject. The percentage of bacteria removed is not the question, but the question is the *number* that are left in the water.

Mr. McCulloch.—What is the number of bacteria in Mississippi River water?

Mr. Holman.—The number varies widely with the season of the year.

Mr. McCulloch.—Is it less when the water is very muddy?

Mr. Holman.—No. It is less in winter, when the water is cool. We find practically that most of the bacteria go with the mud. After the water is allowed to settle for a considerable time it is found quite free from bacteria, but the mud is very prolific.

Mr. Ockerson.—Does this film form on vertical surfaces as readily as on horizontal surfaces?

Mr. Holman.—The results indicate that the film forms not only on the outer surfaces, but also in the interstices between the grains of sand. The health authorities of Germany make no dis-

tinction as to the character of bacteria in filtered water. They simply make the broad requirement that there shall be no more than 100 bacteria per cubic centimeter, regardless of the kind.

Mr. Ockerson.—Have the Worms elements been tried on muddy water?

Mr. Holman.—They have no muddy water to try it on. The Rhine at that place gets slightly muddy, so that they would clean their old sand filters as often as once in three days. But what they call muddy water we would here call fairly clear water.

A Member.—What is the advantage of compressed air? I have seen it used in one filter, divided very finely and forced in.

Mr. Holman.—You may refer to the mechanical device that produces a back flow through the filter. That you will find in the filter of the American Tripoli Company, which consists of a tripoli stone cylinder inside of a small iron boiler. The raw water is allowed to enter from the inside of the stone and filter outward though it. The upper part of the iron boiler is used as an air chamber. The filter is cleaned by reversing the current of the water, the flow being due to the elasticity of the air in the upper part of the chamber; but the compressed air is not run through the stone.

A Member.—In the filter to which I refer compressed air is brought through a pipe and forced through the sand.

Mr. Holman.—I have not seen it. I should anticipate that it would be very detrimental, so far as the bacteriological result is concerned. In Germany the effort is to keep the sand free from air, so as to keep the sand compact, in order that it may afford a firm support for the film.

Mr. Branch.—What was the principle of that mechanical filter used at Worms; was it a stone filter?

Mr. Holman.—The term "mechanical filter" is used to designate a sand filter in which the bed is cleaned by revolving rakes driven by machinery while the current is reversed. The Fischer sand-plate filter, to which I have referred as the Worms element, is simply a hollow square slab of artificial stone, which is set up on its edge, through which the water filters inwardly, and which is cleaned by merely reversing the current. The problem was to economize space by making sand stand up on edge, and it was solved by mixing with the sand a sufficient amount of glass and subjecting the mixture to a temperature that renders the glass plastic and sticky. The result is a porous stone, composed of sand and glass, and not affected by any ordinary waters or ordinary acids.

Mr. Branch.—Is there any danger of one of those elements getting broken?

Mr. Holman.—That may happen. And in arranging their filter plants the elements are arranged in batteries, so that the output of the individual batteries can be examined independently of that of the whole plant. Thus, the output from each filter at Worms is carefully examined every day, so that any difficulty can be detected.

Mr. Sanger.—Then a fault might run twenty-four hours without being found?

Mr. Holman.—It might run twenty-four hours. They generally take two samples a day from the filter.

Mr. Ferguson.—Is the nature of the bacterial film sufficiently well understood to afford an explanation why, at the city of Worms, when the current is skillfully reversed, the film remains intact and serves the purpose of a new film?

Mr. Holman.—A large portion remains on. Of course some is torn off. Just what that film is I could not find out, and the engineers handling the problem do not seem to care to know. They get certain results, meeting certain requirements of the German Government; and with what particular bacteria constituted the film they had no concern.

Prof. Johnson.—Do you know whether reversing the flow in the Pasteur filter, in muddy water, cleans it completely or only partially?

Mr. Holman.—If the reversed current is under sufficient pressure it will clean the tripoli stone filter of tubular form, provided the reversal is made from the outside to the inside, but not otherwise. The filter being circular in shape, the current passing inward acquires increasing velocity.

Prof. Johnson.—Pasteur tubes could not be cleaned in that way?

Mr. Holman.—I should say not. It is possible with the tripoli stone, but I have not tried it with others.

A Member.—How much water per inhabitant do the Germans use, as compared with what we use here?

Mr. Holman.—A little less than half.

A Member.—How many gallons do we use now per head per day?

Mr. Holman.—From about seventy-five to a little over one hundred, depending upon the time of the year.

A Member.—Is the meter system used in Berlin?

Mr. Holman.—Yes, the meter system is used in all the German municipalities.

A Member.—As well as in England?

Mr. Holman.—Yes.

A Member.—Is the entire supply in every case filtered, or is a distinction made as to the purpose for which the water is to be used?

Mr. Holman.—In cities having a filter supply the entire supply is filtered. In some cities the double system of supply is used, as at Cologne, where they have one supply for domestic use and another for general use. But that is quite rare. Hamburg filters its entire supply, and so do Berlin, Bremen and Worms.

Mr. Robert Moore.—Several years ago I gave to this subject sufficient study to impress me with the great value of the recent discoveries in filtration, and of their great and growing importance to our own city.

Nearly every city suffers sooner or later from the injurious effects of the increasing density of population in the watershed from which it takes its water supply, so that a city which to-day has a pure and wholesome supply is apt in a few years to find it polluted and dangerous. As showing how danger of this sort may be averted, the discovery, made ten or fifteen years ago, that filtration through sand is not only a process of clarification, but also a process of biological purification, is to all cities one of the most important discoveries ever made. No city can safely neglect the study of this subject in the light of its own local conditions, so that when the need arises it may be ready at once to adopt those methods which are best suited to its own peculiar needs. And in view of the approaching completion of the Chicago drainage works, which will throw into the Illinois River, and thus into the Mississippi, an enormous volume of sewage, there can be no doubt that an exhaustive study of the best methods of filtering our own water supply is a matter of the utmost importance to the city of St. Louis. I am glad, therefore, that Mr. Holman is at work upon this subject, and I trust he will receive from the members of this Club all the encouragement and assistance in their power.

With such a study, many of the difficulties with which filtration is now beset will undoubtedly disappear. For example, the cost of cleaning filters, to which Mr. Holman alludes, will, I am sure, be very greatly reduced. In Europe the problem of the reduction of the labor cost of any process receives far less study than in America. Methods are contentedly borne there which would not be tolerated in this country. For example, at the sewage

reservoirs in Boston harbor the work of operating the gates which discharge the sewage is done by three or four men, whilst at Barking, near London, the same work requires a small colony. The reason for the difference lies in the fact that at Boston the gates are operated by machinery, which requires only to be started. I feel confident, therefore, that, when we get seriously to work at the problem, the labor cost of operating and cleaning filters will be so greatly simplified and reduced as to be no longer burdensome.

Prof. Johnson.—Mr. Chairman, I think the best service the rest of us can render to this city and the Club is not to explain how our water shall be clarified, or to theorize on how it ought to be done, but to insist that it shall be done. I know of nothing that could possibly happen to St. Louis that would be of such tremendous value commercially, to say nothing of its sanitary value, than the filtration, or at least the clarification, of our entire water supply.

We who have lived here for some time forget how we regarded the character of the water supply when we first came, and we now rather ignore it and laugh at the fuss that our friends make over it when they come here and see it for the first time. But really we are regarded by other communities as little better than the inhabitants of the Philippine Islands, or of some other half-civilized region. And we cannot convince them that this water is fit to drink or to use in any domestic way.

I came to St. Louis from Detroit, had gone to school in Michigan and had been for many years in what you might call, with reference to St. Louis, the "Chicago atmosphere." I now think St. Louis is one of the best cities in the world. We who know about these matters know that, on the whole, our water supply is very wholesome. The mere fact that we have the lowest city death rate in the world is sufficient to show that our water supply is not unwholesome. Mr. Holman said the sedimentation it gets in the settling basins removes the bacteria so thoroughly from the water that it is no longer able to furnish the seductive coating required to remove the few that are remaining. I sometimes say to my friends of Eastern origin and prejudices that the water here, after the mud is removed, is very much better for having had the mud in it. This proposition is a novel one to them, but it is not so to us; we know that the Missouri River water, after being clarified, is very much better than the upper Mississippi River water, from the very fact that the Missouri water has had the mud in it. What difference does it make whether we filter the water through the ground or filter the ground through the water? There is no difference. Now we filter our ground through the water; we make

it almost thick with good clean clay and then we let it settle, and that filters the water just as effectually as though we filtered our water through the ground.

The health argument is not the strongest one in favor of filtering our water, and I dislike to see it pressed, because, in the first place, I believe there is not much force in it, and, in the second place, it unnecessarily alarms both our own people and strangers to our great disadvantage and to no profit. But we can work the commercial argument, the idea that money spent in clarifying our water supply is going to bring many times its value in a financial return. This is an argument that appeals to every citizen, and especially to the people who pay the taxes and water rates. I think merely clear water would be worth millions of dollars a year to this city at a small calculation, and the benefits would appear in a thousand ways, to say nothing of water entirely free from bacteria. Perhaps when filtered it would not be very much freer from bacteria than if simply clarified; but in either case it would be a water which would be decent, and would be like the water that other people use, and we would be regarded as at least civilized and white—which is more than can be said now.

Mr. Robert E. McMath.—Our Water Commissioner had the enterprise and the good luck to go to the other side of the water and learn something, without any cost to the city of St. Louis, and he comes back and generously gives the city the benefit of what he learned. I am rather under the impression that this comes about fifty years ahead of time; that is, what he has learned is so far in advance of the ideas prevalent in this community that he will be a very old man before the community catches up with him.

As Prof. Johnson puts the situation, one important thing which we can expect to gain by the betterment of our water supply is to render it less repulsive to the stranger. I well remember the first time I ever turned water into a washbasin in the city of St. Louis, and the astonishment with which I waited to see if it would not get a little better. I remember the repugnance with which I undertook to wash my face in such stuff, but that, you must remember, was a good way back. You young men never saw such water coming from a hydrant.

For a good many years the city of St. Louis has been trying to rid herself of that trouble. When it inaugurated the system of settling basins it was expected that the quality of our water supply would be rendered entirely satisfactory. For a time it was satisfactory, because of the contrast with what we had had before. But time passed on and the basins had to be worked far beyond their

capacity. Next works were completed at the Chain of Rocks. I think there was some further disappointment then, for the benefit that was realized fell, like other things, below the expectations. The next step in the process, according to Mr. Holman's logic, is that the water has got to be clarified, both on account of Prof. Johnson's argument and as a preliminary step to the further and complete purification which it is proposed to accomplish by filtering.

Now I am of the opinion that, for a good while to come, our people will be satisfied if they get the full result of clarification, so that the water which comes to them from the hydrant will be entirely free from mud and from its present repulsive appearance. I am inclined to think it will be a long time before we deem it necessary to go to the additional expense of filtering all the water used in the city of St. Louis, as that would render it absolutely necessary that the supply should be delivered through a meter, and every man would pay for the number of gallons that he uses or wastes.

Mr. Holman has not succeeded in making me an advocate of the filtering of the whole water supply, simply for the reason that, since I have been connected with the city affairs, I have got into the habit of being satisfied to do the best we can, and to let the ideal condition wait for future generations to develop. I think the present generation of the city will be very well content if they realize a complete clarification.

The situation, as I view it, is: Mississippi water during three-fourths of the year is so heavily charged with mud that it would clog any kind of filter. As the first preliminary to filtering, it must therefore be cleared of nearly all of its mud burden. It is not practicable to furnish sufficient area of settling basins to clear our entire water supply by natural sedimentation. Hence resort must be had to some form of coagulant. Clarification by a coagulant will be so complete as to remove the repulsive appearance, and the water, after the sedimentation secured by the use of a coagulant, will have so small a residue of bacteria that the essential bacterial film will be very slow of formation, if formed at all, be the surface sand or stone, natural or artificial. The logic is clear to me up to the point of clarification, but it fails as yet to lead me to advocate filtration for the entire water supply of St. Louis.

Mr. Julius Pitzman.—To the matter of sanitary filtration of the water used in St. Louis I have never given much attention, but I agree with Prof. Johnson that it is of the utmost importance, for the development of our city, to take initiatory steps for the

clarification of the water; and we should, furthermore, pay some attention to the condition of the river and, as far as practicable, prevent its pollution.

In a very short time the sewage of Chicago will be discharged through a canal into the Illinois River, which empties its waters into the Mississippi River some twenty miles above St. Louis; and, irrespective of the question whether or not the flow of the sewage thus discharged will have an injurious effect upon the health of our inhabitants, a large portion of our population will think that it has, and will ask for the abatement of this nuisance. We may therefore have to file an injunction against Chicago, to prevent the further discharge of sewage. In case such suit is brought we will find ourselves in the position of asking the abatement of a nuisance, while we ourselves are discharging all sewage and offal into the river and creating a similar nuisance.

If a person of æsthetic refinement visits the river bank or takes a sail in front of our city he will return in disgust, and with a very poor opinion of the people who permit the river to be so horribly polluted. It seems to me that the time will soon come when cities will be prevented by proper authorities from discharging their sewage and offal into rivers, and when they will be obliged to build intercepting sewers, so as to separate sewage from storm water.

As the filtration or clarification of all the water used by us will greatly increase the expense connected with our water works, it has been suggested to introduce water meters to prevent the wasting of water. Dr. Glasgow has remarked that he considered it inadvisable to stop the waste, and I have heard the argument frequently made by prominent physicians that the waste water flushed the sewers. I wish to call their attention to the fact that all the water used by our city is pumped through four or five pipes of 36 inches diameter, and that if this quantity of water is discharged through the district sewers, with hundreds of branches, each having a diameter of at least 12 inches, it cannot possibly flush all of such sewers or effect any improvement of their sanitary condition.

Arrangements could easily be made by which, during a dry season, the valves of the water pipes are opened and the water thrown into the manholes at the summits, and thus one set of district sewers after another could be flushed in a systematic and effectual manner at a very much smaller expense than by wasting over ten million gallons of water daily without the slightest benefit to the sanitary condition of our sewers.

Mr. Russell.—Some years ago, when Colonel Flad was President of the Board of Improvements, the St. Louis Water Department made some experiments on filtration. At that time Colonel Flad had an idea that upward filtration was the proper thing, and so a filter was fitted up (10 feet square I think it was) to try upward filtration. We also had some small experimental filters made upon the European plan. Those filters were operated for quite a long time, and we have the records of all those experiments. To the best of my recollection, the experiments showed pretty conclusively that sand filtration, as nearly as could be told from such a small experiment, is a very expensive process with our water. The sand would have to be scraped very frequently, and the capacity of an acre of sand filter would be very small at a time when our water was bad.

Since Mr. Holman has been Water Commissioner we have had a few small experimental filters built. They were all of the so-called "mechanical" type. The largest was about four feet square. They were used experimentally for some months, and a great many difficulties were met with. The quality of the water changed constantly, and there were many things that affected the filtration, *e.g.*, the temperature affects the rate of filtration. In fact, there are many difficulties in getting the mechanical filter to work properly, and experimenting with it is very unsatisfactory, unless there is a large fund at disposal.

In our mechanical filters aluminum sulphate was used through all the experiments, and pretty fair results were obtained on the whole; but it is difficult to tell, from a small experiment, just what would be the cost of a plant of sufficient capacity for our whole water supply. We have not had experiments enough to determine that. We have made several plans and estimates of the cost of a plant to filter our supply, both on the American and also on the European system. Filtration and the use of meters must come together. If we have filtered water we must reduce the consumption by the use of meters. Now these meters cost a good deal of money, but they would check the increasing consumption of water. It has been the history of all large cities that the rate of consumption per capita increases steadily and at a quite rapid rate. This is true of all the large cities of America, and I believe is also true of some cities in Europe.

Now the use of meters would hold this growth in check to a large extent, reducing the rapid increase in the per capita consumption. I have attempted, with insufficient data, to estimate the reduction and the cost of filtration, and I believe that the city,

over a number of years, would actually be spending less money by having filtered water and using meters than it would spend under the present system, allowing the consumption of water to increase as it does now.

I think Prof. Johnson hit very close to the mark in his words about clearing the water. As Mr. Holman indicated, a great proportion of the bacteria go down with the mud in the settling basins. I think, moreover, that the more mud there is left in the water the more bacteria are left in it; so, as nearly as I can find out, it is when our settled water is the muddiest that it contains the most bacteria. The water of the river is worst when the river is rising, when the ground is broken up by the frost and a general washing of the whole country is taking place, bringing down all sorts of impurities from forest lands, etc. Our river picks up the mud and most of its bacteria at the same time and in the same way, and deposits the mud and bacteria at the same time and in the same way. Any method that removes the mud is certain to improve the water, by reducing the number of bacteria in it. I think, therefore, that if we can get clear water it will certainly be pretty good for drinking.

Dr. Charles R. Sanger.—I have never had an opportunity of making a very extended chemical and biological investigation of the Mississippi water, but so far as the practical part is concerned I am fully in accord with Prof. Johnson in what he said about dollars and cents. I think this is most important, and the chief way in which the public are to be reached. But I do not agree with Prof. Johnson in the opinion that the water is wholesome. While we have, it is true, a small death rate in St. Louis, we are not quite free, and not as free as many other cities, from digestive troubles due to bacteria not strictly pathogenic. I think this water is responsible for a great deal of the enteric troubles we have in St. Louis. As to the presence of pathogenic bacteria, I have had in my own family a child sick of typhoid fever, and I am absolutely certain, by excluding every other possible source, that the typhoid fever was due to accidental drinking of unfiltered St. Louis water. I am absolutely certain that the typhoid fever epidemics we have had here have come from St. Louis water.

As to the removal of the bacteria, sedimentation can accomplish this to a large extent, but it does not remove all; and even if the water were also coagulated, that would not remove all of the bacteria. It is absolutely necessary to filter the water, for then alone are we sure that the water is free from bacteria.

2

The German limit of 100 bacteria per cubic centimeter is very easily reached, and is reached constantly by filters in operation in the East, notably by that at Lawrence, Mass. Mr. Holman has proceeded in his usual conservative way; I think he has done about as he ought to have done, but, of course, filtration cannot come if there is no public demand, and there *is* no public demand in St. Louis for filtration. Almost every one is satisfied to drink the water as it is, or would be satisfied with coagulation, to simply make the water more attractive for drinking; and they would be content by so doing to get rid of most of the bacteria. I should have liked Mr. Holman to call in the assistance of some men in this country who have been making a study of this matter for years. But without their assistance he has proposed what seems to me a very practical plan; which is, as far as I understand it, to make use of these present settling basins, which he has thoroughly under control, for coagulation by aluminum sulphate or any other coagulant which may seem practical; to get the bulk of the matter precipitated out in the basin (and this precipitate can be readily and cheaply removed), and then run the clarified water through the filter. Now for this water something like the Worms system would seem very appropriate, if there was no difficulty in forming the film on the outside of the elements. I am very sorry indeed that Mr. Holman's plan for an experimental filter plant, to filter 50,000 gallons, could not have been adopted, particularly because the city government ought to have a chance to see what he could do on what would be called a somewhat large scale; large enough, if he had been allowed to try it, to show exact results, after which he could go ahead at once on a larger plant. There is no body of men better fitted than the Engineers' Club of St. Louis to urge such a movement as that for the filtration of the St. Louis water, and they should use every effort to bring the matter about.

Mr. B. H. Colby.—I agree with what Dr. Sanger has said about the experimental plant. This was first brought to public attention by an ordinance drawn by the Water Commissioner and sent to the Municipal Assembly by the Board of Public Improvements about two years ago.

It went into a pigeonhole, where other meritorious ordinances for public work have found permanent resting places before, and, as you know, nothing was done. Sometimes it seems almost disheartening to those engineers who are trying to give this city pure water to have their efforts rendered inoperative by the lack of the necessary legislation to carry out their plans. I think the commercial demand would be almost entirely satisfied if our water

were clarified. If we had clear water to wash and bathe in probably not over 5 per cent. of the people would insist upon filtration. To a large proportion of our population *clear* water means *pure* water. Those who know the danger that may be in perfectly clear water will continue to demand filtered water, and that their demands will ultimately secure the filtration of our water I have no doubt whatever. Just when this will be accomplished we cannot at present predict.

Much legislation is necessary before the city can be placed in a situation to supply filtered water to its citizens. After the filter plan is fully completed, it cannot be successfully operated until provision is made for the employment of a corps of competent chemists and bacteriologists. These men should make daily tests of the water passing through each filter. They should live in houses owned by the city and located adjacent to the filters. Their qualifications for their positions should be capability and fitness for the particular work to be done by them. They should hold their positions for life, as should the higher officials in charge of our water works plant. Legislation is needed to accomplish all this, and much more, of which there is not time to speak to-night; but before we can secure the *good* legislation we must rid ourselves of perniciously bad political practices. Our citizens must learn the importance of having their public works in the hands of the best men obtainable.

When this is learned they will demand that only men of the highest attainment and fitness be intrusted with the design, construction and maintenance of our public works. They will go further and demand the separation of public work from all political interference.

When this conception of the conduct of our public work has been bred into the daily thought of our people their action will be quick, the results permanent. Unless the desire for a better order does grow up among our people we will have national degeneration, and our children will see jewelers reporting on our water supply and harness-makers building our filters.

Dr. Glasgow.—I doubt whether it is desirable to limit the amount of water used. If we filter we will have to have meters, limiting the quantity of water. Is that desirable? I have always been of the impression that the more water was used the better the health of the community, even if that water was not as good as it ought to be. The problem in European communities is different from ours. I question, also, whether clearing the water of sediment renders it wholesome, and whether leaving the microbes in the

water is in all cases hurtful. We who have lived along the Mississippi River, and have drunk its water, feel that mud is not so very unhealthful. Dr. Sanger has not lived here long enough to get used to it. He brings his Eastern prejudices with him, and I have no doubt that if he lives here long enough he will appreciate this water more than he now does. Then, again, cases of typhoid will occur in every community. I suppose there is no community on the face of the earth that does not have them. We have some here. If Dr. Moore will look at the statistics of large cities he will find we have less than our proportion. The water here, impure as it is, is better than the clear water they have in other cities; and if we succeed in getting rid of the mud the bacteria will be cast down with it, and we will have the finest water in the world. No water tastes like the Mississippi River water. European communities seek to get rid of bacterial life, while here we seek to get rid of the mud. When that goes the bacterial life goes with it.

Dr. Sanger.—Without seeking to controvert Dr. Glasgow, I want to say I have no prejudice. I lived twelve years of my life away from the East, long enough to be away from Eastern prejudice.

President Bryan.—The objections urged against the reduction of the per capita consumption by the use of meters do not apply, for some minimum charge will be fixed. The charge will be upon a sliding scale, and the minimum fixed at a consumption ample for all reasonable requirements. The idea is to make a distinction between ample consumption of water and absolute waste.

Mr. Moore.—In regard to the claim that the larger the consumption of water per head the better the health of a city, I think it is only necessary to refer to Chicago. The consumption there is about 160 gallons per head per day, or nearly 50 per cent. more than in St. Louis. Yet the typhoid rate of Chicago is double that of St. Louis, and the danger from using the Chicago water is so well known that the daily papers there are constantly urging people not to drink it unless it has been boiled.

Mr. McCulloch.—Does the Mississippi River water, after it has been settled and the mud taken out, contain more than 100 bacteria per cubic centimeter?

Dr. Sanger.—The question can hardly be answered except by experiment. The number of bacteria varies with the condition of the water.

President Bryan.—Would it contain more than that number before it is filtered?

Dr. Sanger.—Of course. Yes, at all times.

President Bryan.—Have there been any regular biological experiments conducted in this city by the Water Department?

Mr. Russell.—While making experiments with mechanical filters we took a few gelatine plates, and the results agreed quite nearly with those obtained elsewhere with mechanical filters. But we kept no biological record of the water from the river or water from the settling basins.

Mr. John C. Trautwine, Jr. (by letter).—On the day following the St. Louis cyclone of 1896, and the annual convention of the American Water Works Association at Indianapolis, I had the pleasure of visiting, for the first time, the city of St. Louis, and, by courtesy of Mr. Holman, and in company with Mr. Russell, the water works at Bissell's Point, Baden and Chain of Rocks, of all of which I had read in editing the series of papers descriptive of the works, published in the Journal of the Association for January, 1895, which included papers on the "History of the Works," by Mr. Holman; on "Points of Interest in the Design and Construction," by Mr. Russell; on the "Quality of the Supply," by Mr. McMath, and on "Filtration," by Mr. Moore.

In the annual report of the Philadelphia Bureau of Water for 1895 I quoted freely from Mr. Moore's paper, and reproduced some of his diagrams. In editing Mr. Holman's present paper, therefore, I found myself irresistibly tempted to ask permission to contribute my mite to the discussion.

The first effect of reading Mr. Holman's paper is to deepen my sense of the difficulty confronting the engineer approaching and studying the problem of filtration of municipal water supplies. Not only is the problem in each city distinct from all others, but we are confronted also with startling divergence of views on the part of the doctors of sanitation.

Mr. Holman, recently returned from a visit to the German filter plants, naturally comes highly charged with the doctrine of the efficacy of the bacterial jelly, and informs us that the German experts have scarcely even heard of nitrification. This reminds me that, in conversation with so eminent an expert as Mr. Hiram S. Mills, of Lawrence, Mass., the apostle of intermittent as distinguished from continuous filtration, that gentleman expressed the opinion that the German view of the importance of the bacterial film was without foundation, and that nitrification was the one thing needful. Indeed, I have recently heard that a noted expert in bacteriology has declared that the bacteria in water are of very little consequence.

I am surprised by Mr. Holman's statement that the bacteriological results of so-called mechanical filtration have not as yet been carefully investigated; for, in 1896, Mr. Edmund B. Weston published, as an appendix to the "Seventeenth Report of the State Board of Health of Rhode Island, for the year ending December 31, 1894," a series of tables giving the results of a very elaborate series of experiments with a small Morison mechanical filter at the Pettaconset pumping station at Providence. Elaborate experiments are now being made with a Warren and a Jewell filter in comparison with an open sand filter and Fischer sand plates at Pittsburg, Pa., and the water works public is still waiting for the

results which are one day to emanate from the Louisville experimental plant.

While there is some similarity between the filtration of water through sand and the reverse operation of filtering sand or mud through water, I am hardly ready to say, with Professor Johnson, that "there is no difference" between them. It would appear that when water filters through sand, its particles come into far more intimate and effective contact with the solid particles than during the reverse operation of filtering sand or mud through water. From experiments made a couple of years ago in the Bureau of Water at Philadelphia, it appears that sedimentation, within such limits of time as are usually permissible, is far less effective than filtration in the removal of bacteria. Philadelphia water, however, even at its worst, can hardly be said to compete successfully with that of St. Louis in the matter of sediment.

I regret that Mr. Russell has not given us some idea as to the results obtained with upward filtration under Colonel Flad. If, as Mr. Mills declares, the bacterial film is of little account, we might expect good results from upward filtration, in which that film has little chance to form, and in which the sediment falls away from, and not upon, the bed, and in which the cleaning is effected by simply reversing the current, sending it downward through the bed. Cleaning may thus be readily effected under ice, so that the difficulty of cleaning the filter in winter, or the necessity of providing a roof for it, may be obviated.

Philadelphia now consumes about 200 gallons of water per head per day, and a total quantity equal to that consumed by the four-fold greater population of London. Naturally, therefore, I am much interested in the discussion on the questions of waste and of meters, especially in Mr. Russell's estimate that the cost of a filtered supply, properly limited by meters, is less than that of an unfiltered supply where waste is allowed to proceed unchecked. This may well be the case where, as in Philadelphia, restriction of waste may mean avoiding the necessity of constructing an entirely new and very expensive system of water supply.

I am heartily in accord with Dr. Glasgow in advocating the free use of water. All that we aim to control is its *waste*, which either inflicts unnecessary burdens upon the community or deprives careful people of a full supply in order that the reckless and unscrupulous may throw water into the sewers without its accomplishing any good whatever. Mr. Pitzman's contention that water wasted into the sewers does not flush them is, I believe, entirely correct.

In Philadelphia, as in other places, we seek to prevent undue restriction in the consumption of water by fixing a minimum charge, as mentioned by Mr. Bryan. This charge is about one-half the regular schedule rate, and consumers save nothing by keeping their consumption below that point.

Until recently I was disposed to endorse Mr. McMath's view that every supply should be metered; but a recent experiment, in which, for our information, we placed meters upon some twenty dwelling houses, showed that all but three or four of these were using water quite reasonably, so that it would have been a mere waste of money to meter them. To meter every supply in Philadelphia would cost the city some four million dollars, whereas, if it were found necessary to meter only say one-fifth of the whole number, the cost would be proportionately reduced.

Fig. 1.

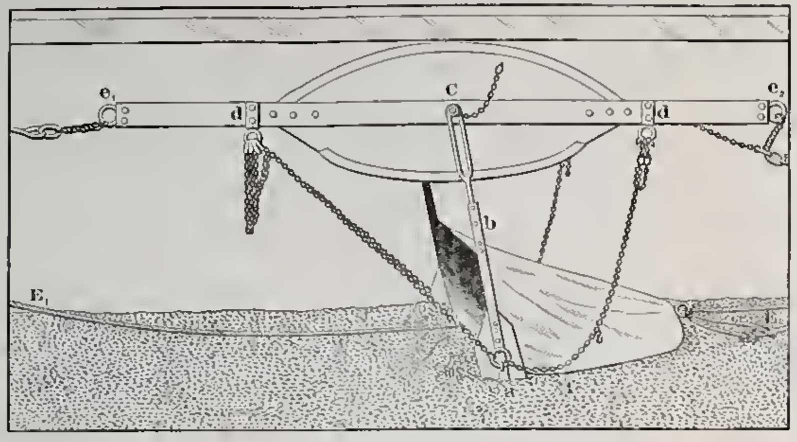


Fig. 2.

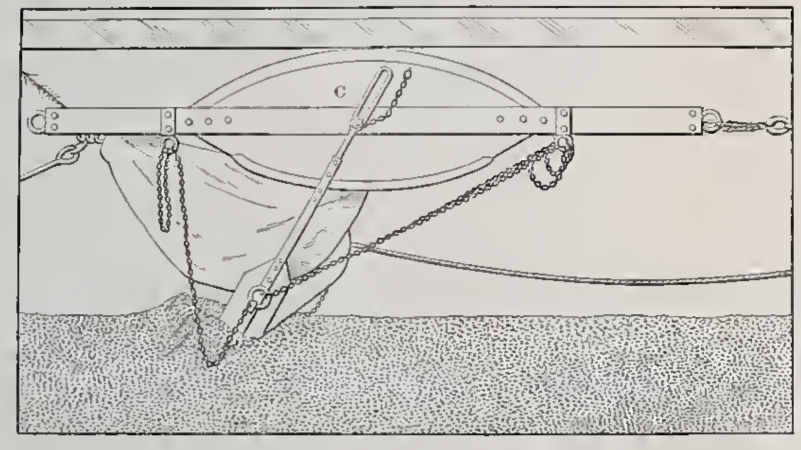
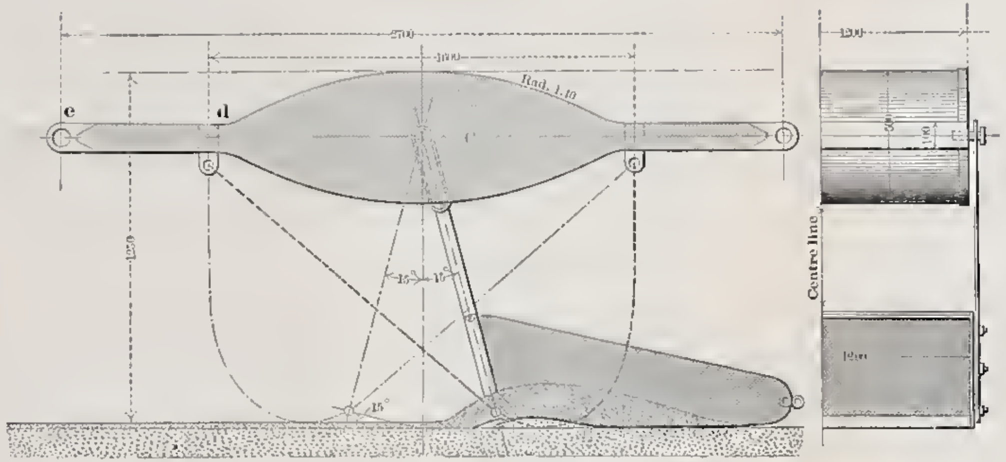


Fig. 2a.



Figs. 1, 2 and 2a. Apparatus for scraping filter bed under ice (Hamburg).

Fig. 3

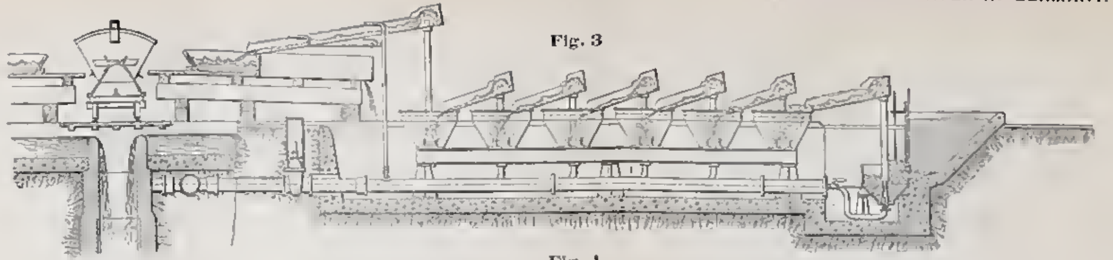
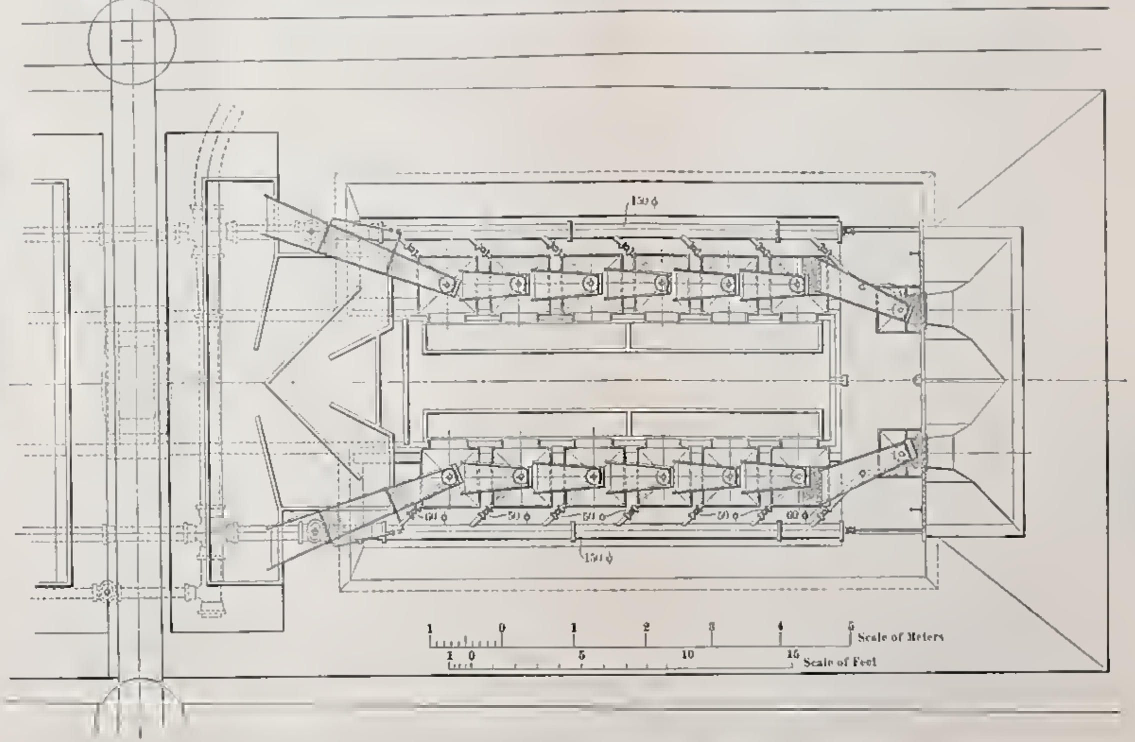
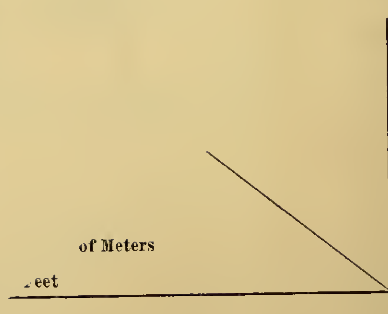


Fig. 4



Figs. 3 and 4. Apparatus for cleaning sand removed from filter beds (Hamburg).



oeds (Hamburg).

Mr. Pitzman's mention of the relations between St. Louis and Chicago, in the matter of stream pollution, calls forcibly to mind the position at Philadelphia, which, if it appeals to the State Board of Health for protection from pollution of the rivers above it, is apt to be met with the charge, only too well founded, that Philadelphia sends most of its sewage through the Delaware to the towns below.

Noting Mr. Holman's reference to double filtration, in which the water is passed through two successive filter beds, I am reminded that Mr. Halbertsma, engineer of water works at the Hague, in Holland, advised me recently of some experiments of his in that line. I have not the exact figures at hand, but my recollection is that the first filtration removed nearly all of the bacteria, leaving little for the second filtration to do. On the other hand, Mr. Halbertsma wrote me, in April, 1897, that double filtration at Schiedam was "quite a success," and that he was designing other works on the same system.

At Reading, Pa., is a two-story sewage filtration plant, where the sewage, after passing through a bed of coke at the receiving station, and then through a long conduit, falls upon an upper bed of sand 18 inches in depth; after passing through which, and falling 10 feet through the air, it passes through a second sand bed 3 feet deep. Each of the sand beds rests upon a 6-inch layer of broken stone, and the lower bed is covered with 2 inches of small stone, in order to protect its surface from the abrasion of the falling liquid.

The Pennsylvania Sanitation Company, which built the plant, publishes the following results:

PERCENTAGE OF BACTERIA REMOVED.

After passing.	Oct. 9, 1896.	Oct. 19, 1896.
Coke	29.68	66.83
Upper bed	98.11	99.54
Air	99.54	99.84
Lower bed	99.92	99.9996

Noting, in Mr. Holman's paper, that previous filtration deprives the water of its power of forming the necessary film on the second bed, and that prior sedimentation also interferes with the formation of this film, I am moved to ask what has been the experience, in this respect, in London, Hamburg and other cities where sedimentation takes place before the water passes to the filter bed.

It is rather remarkable that the cleaning of the bed in Hamburg, by the machine which Mr. Holman describes, should, by packing the sand, reduce the relative output, whereas cleaning in general naturally increases the rate. Cannot this difficulty be obviated by a rake or harrow following the machine?

Note by Mr. Holman. At Hamburg the action of the clay and sand, in the sedimentation basins, is not sufficient to drag down enough of the bacteria to prevent the subsequent formation of the film on the filter beds.

NOTES ON THE MATHEMATICAL THEORY OF NAVAL ARCHITECTURE.

By Joseph R. Oldham, N.A., Member of the Civil Engineers' Club of Cleveland.

[Read before the Club, May 24, 1898.*]

On Wednesday, July 7, 1897, a grand dinner was served in the Kings Hall, when the First Lord of the Admiralty made a clever and humorous speech, in the course of which he said that when the low freeboard turret ship "Devastation" was completed his numerous technical advisers placed him in a dilemma, many eminent naval experts having told him that if he allowed that warship to proceed to sea he would be guilty of murder, while other no less eminent and equally numerous authorities on naval affairs assured him that he would be sacrificing the prestige of the British Navy if he did not send her to sea.

His position for the moment was by no means an irresponsible one. She went to sea, however, and he has not been formally accused of breaking the sixth commandment, and, from all he could learn, the prestige of the British Navy is not seriously impaired.

Mr. Goschen added that, in addressing so representative a gathering of distinguished naval experts, he must sincerely compliment them on their marvelous achievements, but he had to tell them of one thing in connection with naval architecture they could not do; it was a miserable little physical defect they had never mastered—they had not yet designed a vessel to prevent sea-sickness.

Perhaps Mr. Goschen had Sir. Edward J. Reed in mind when he made this latter remark, for, if I am not mistaken, it was no less a personage than the ex-Chief Constructor of the British Navy who, when the writer was a boy, designed a large passenger steamer with suspended or swinging cabins to prevent *mal de mer.* I think this scheme proved anything but a success; however, the Welsh proverb teaches us that "failures are the pillars of success." And in his case the proverb proved literally true, for to-day there is not a naval architect more highly thought of than the same Sir Edward. It may be true that his early reputation as a cautious chief constructor was somewhat tarnished by his supposed responsibility in connection with the design, or perhaps I should say in connection with the commissioning, of the ill-fated "Captain."

*Manuscript received June 9, 1898.—Secretary, Ass'n of Eng. Socs.

But be that as it may, his services to the body of naval architects and shipbuilders of the wide world have been liberal and grand in the extreme. As an author, his language is dignified and convincing; his illustrations are clear, concise and correct; his imagination is superb; he exalts hard and dry subjects into the region of romance. As a writer upon the science of naval architecture he compares not unfavorably with Scott as a novelist or historian.

There are many elegant writers among the naval architects, such as Elgar, White, Barnaby, Martell, Gray, Milton, but none, I verily believe, so justly popular as Sir Edward, and none more honorable. His clear, sensitive mind appears ever on the alert lest he should inadvertently assume to himself the productions of another, or fail to award due credit where credit might be due. What I am trying to convey will be better understood after reading the preface to his exhaustive work on the "Stability of Ships."

The literary event of the congress was undoubtedly the reading of the paper by Sir Edward J. Reed, on the "Advances Made in the Mathematical Theory of Naval Architecture During the Existence of the Institution." Referring to the longitudinal strength of ships, he quoted from a paper by the late Mr. John, showing that in a vessel over 400 feet long the maximum tension was found to be 8.85 tons. These forces were not sufficient in themselves to cause rupture in a vessel well built of good materials, but they might be sufficient to cause very considerable straining, which, if not attended to in time, must weaken the vessel to the point of danger. With reference to the transverse strains of iron merchant vessels in docking them, he mentioned the case of a vessel supported by the keel alone, and with only breast shores to keep her upright; and demonstrated the need of great transverse strength, especially in the engine and boiler space, where the localized weights of the machinery increased the strain at the middle line and the bilge.

In the all too brief discussion which ensued, the writer of the present article pointed out the improved system of docking practiced on the American lakes, where the bilge blocks are drawn under the vessel before the water is pumped out of the dock; and he asked Sir Edward whether the absence of this bilge support in their system would not account for some of the straining observable at the bilges and bottom of broad ocean steamers, which were sometimes placed in dry dock resting on the keel blocks only, and with the coal bunkers in various stages of fullness, and added that the bilge and bottom butts of lake steamers were seldom found in

as bad condition as ocean vessels. It should not be supposed that the immunity from such straining in lake steamers can be accounted for by want of hard work or by shortness of service, for we have some very old iron vessels. Indeed, he believed that the oldest iron steamer in active service in the world was now afloat on the American lakes.

In the paper mentioned, Sir Edward said:

"At a conference of naval architects, held a few weeks ago in London, I drew attention to the remarkable nearness that exists between the strengths of ships and the estimated strains at sea to which they are subjected, pointing out that shipbuilding practice presents us with no such large "factors of safety" as we all require in bridges and other land constructions. Sir William White and other speakers truly pointed out that practical experience has made it certain that no such large factors of safety are really requisite in ships. But it seems equally certain that no one can say at present what the factor should be, even as regards longitudinal strength, and its determination is one of the results to which we may confidently look forward."

Speaking of the metacentre, Sir Edward said:

"Of late years some persons have fallen into the habit of calling a large number of points, not in the vertical center line of the ship, metacentres. This is a mistake, and in dealing with ship calculations nothing should be called a metacentre that was not situated in the original upright axis of the ship. In other words, there is but one metacentre,—viz, that due to a slight inclination from the upright where the vertical through the center of buoyancy intersects the original center line of the ship in her upright position."

It was pointed out that Prof. Ocborn Reynolds took serious objection to the confusing use made of the word "stability." He said:

"In recent literature on naval architecture the term stability occurs over and over again in the sense of righting moment, and this under circumstances where the context shows the meaning to be incompatible with any meaning that can be given to the word, for stability must refer to some position in which the ship is stable;"

and he went on to develop this objection at some length, particularly pointing out that

"the righting moment exerted by the buoyancy at considerable angles of inclination is often found to be effective, not in restoring the body to an upright position, but merely in restoring it to some other less inclined position, in which it will remain if left free to do so. The truth of this is well known to most naval architects, but it may be well to give the curve of stability of an actual ship illustrating the case by Fig. 1. This ship has a negative metacentric height of 6 inches, and she lolls over 20° before she begins to acquire an opposing moment. From 20° to nearly 80° she has a righting moment of precisely the same kind as an ordinary ship; but this moment only returns her toward and not to the upright position. Again, when we speak of righting levers and righting moments (which are but conditional measures of rotating forces) as identical with or equivalent to

stability, we reach the anomalous position of having, even in a ship of very great stability, in the popular sense of the term, no stability at all when she is upright, or, as in the case just illustrated, none at all when she lies free and at rest at 20° of inclination."

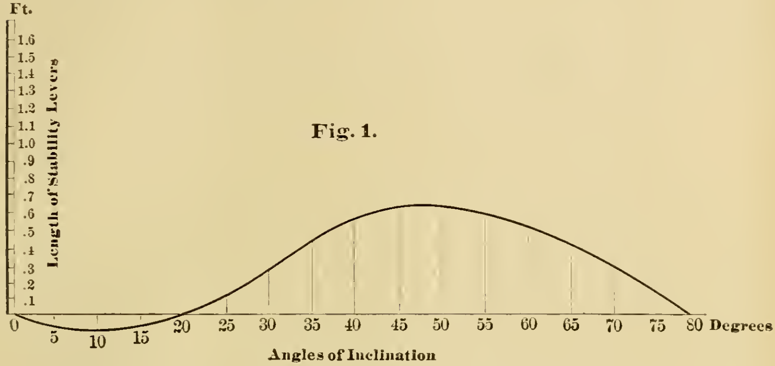


Fig. 1.

With reference to the loss of the "Captain," a criticism of Sir Edward's paper (1868) said:

Fig. 2.

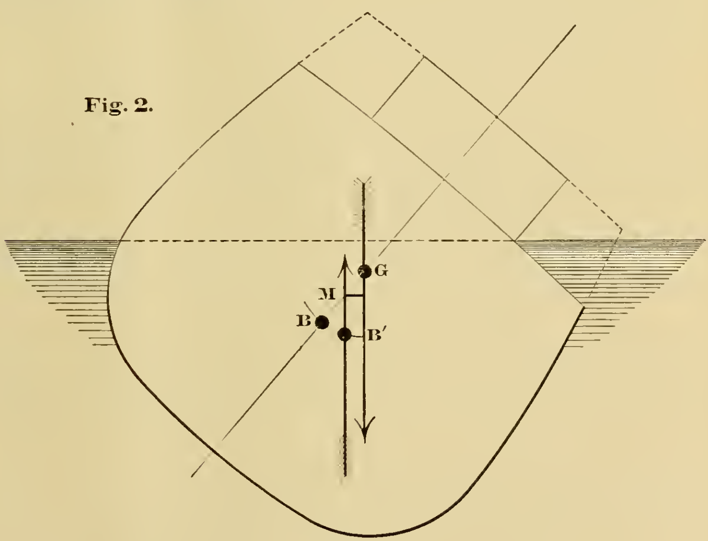
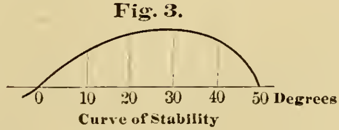


Fig. 3.



"It showed conclusively that instability would occur in such (low free-board) vessels at a very moderate angle of inclination, and illustrated the contrast, as regards stability and safety, existing between rigged ships with high freeboard and those with low freeboard. . . . This paper did not succeed, however, in impressing members of the profession with the neces-

sity for more complete calculations of stability, and the subject remained in comparative obscurity until the loss of the 'Captain' forced it into painful prominence."

The "Captain," it may be remembered, was a low freeboard ship, and might be compared in that respect to a deeply laden merchantman, such as the "Marlborough," which also capsized. See Fig. 2 as an approximate illustration of that disaster.

Sir Edward then referred to a *light* vessel, and said:

"It unhappily required a further incident and another calamity to open men's eyes to the very opposite danger,—viz. that of ships capsizing at light draft. In 1883 the 'Daphne' capsized on the Clyde during launching, and I was sent down by the Government to inquire and report upon the accident. The inquiry developed several facts which showed how much need there was for large extensions of stability calculations. It proved that ships of modern type are sometimes characterized when floating light by very abnormal deficiencies of stability in inclined positions. The 'Daphne' herself possessed not only small stability, but a slow growth of it with increase of inclination. No curve of stability at the launching draft had at that time been calculated for any ship. Sufficient *initial* stability had been always regarded in ordinary ships as a guarantee of sufficient stability at all angles. Even the highest of our authorities at home had assumed this to be the case. All this proved, however, to be quite erroneous."

As to ballasting of merchant vessels, the author said:

"The use of water as ballast for merchant ships is, I fear, leading to some danger and loss, not because of any inherent defect in its use for this purpose, but because in applying it to the various objects of ballasting, trimming and replacing fuel that has been consumed more knowledge is required than is sometimes available, and more water ballast is needed than is sometimes arranged for. This, however, points not to defective scientific theory, but only to the desirability of extending scientific information."

Suppose a steamer is required to cross the ocean in ballast, where head winds and rough seas may be encountered all the way. It is a matter of great importance that the severe rolling qualities should be reduced to a minimum. To accomplish this the righting levers must not be too long or the moments too great.

In broad vessels the weights carried, such as water ballast, should not be too low down, or uneasy and jerky rolling will result. To obviate this our friends across the ocean have recently invented some ingenious devices. One design is to carry water ballast in the bilges and wings under the upper deck. This arrangement also makes a safe hold for carrying grain without trimming, but, as the flat of the bottom is thus left without an upper bottom, it certainly does not commend itself for our lake trade; moreover, a part of the design is by no means novel. Another arrangement for carrying water ballast appears to me preferable, but I fear the

expense of construction would check its adoption on these lakes, though by such an arrangement an ore carrier might have a very small register tonnage in proportion to dead weight carried.

The error of Scott Russel as to ship resistance, in which he assumed that a ship had to excavate the water or raise it from its center of buoyancy to the surface, was touched upon, and, though this was an extravagant conception of the fundamental work to be executed by the propelling engines, it is certainly true that from point to point the ship has to place itself where the water has just been.

"It is a point worth noticing here what an exceedingly small force, after all, is the resistance of a ship compared with the apparent magnitude of the phenomena involved. Scarcely any one, I imagine, seeing, for instance, the new frigate 'Shah' steaming at full speed would be inclined, at first sight, to credit, what is nevertheless the fact, that the whole propulsive force necessary to produce that apparently tremendous effect is only twenty-seven tons; in fact, less than one-two-hundredths part of the weight of the vessel."

The most striking feature observed in connection with the practical investigations of the International Congress was the many large and powerful battleships building for the Japanese Navy. I will briefly describe one that I examined at the Thames Iron Works and Shipbuilding Company:

The "Shikishima" is 400 feet x 75½ feet, and at 27¼ feet load draft she displaces 14,850 gross tons of salt water, or a little over 16,000 net tons of fresh water, as we usually quote on these lakes. She is to steam at the rate of 18 knots per hour, with 14,500 indicated horse-power.

It is claimed by the builders that the "Shikishima" is the most powerful battleship afloat, being completely armored from stem to stern, from 5½ feet below the water line to 9¼ feet above, with the most modern nickel steel carburetted armor, varying in thickness from 9½ inches to 4 inches on the stem. She is fitted with Belleville boilers.

A Russian engineer, writing about his experience with Belleville boilers, says there were twenty-four on board their steamer, placed back to back with furnaces athwart ships. The steamer had a list to starboard of 10½°. This list caused the tubes of the port boilers to be nearly all bent downwards, and, thirteen of them being out of line as much as one to one and a half inches, were replaced. The uptakes were overheated through too heavy fires being kept up. The labor necessary to keep these boilers in working order was very heavy, and the average consumption of Welsh coal was

from 2.15 to 2.20 pounds per indicated horse-power per hour. These boilers were not fitted with economizers.

The advantages of supplying the boiler with feed-water approximating in temperature to that of the boiler has long been recognized. Its beneficial effects, as regards boiler preservation and reduction of racking stresses, due to variations of pressure, are well established. Even when the heating steam is taken from the boiler direct, so that theoretically there is neither a gain nor a loss of heat by the process, large numbers of vessels in which such feed-heaters are fitted report an appreciable gain (some claim 10 per cent.) in economy, and that when using the feed-heaters steam is more easily maintained than when they are not in use.

When the heating steam is taken from the last receiver of the engine, or the exhaust steam of any engine, a gain in economy can be clearly shown to exist theoretically in some cases as high as 16 per cent. Feed-water heaters are now being fitted in large numbers of vessels of the mercantile marine, and the results obtained justify their adoption.

As there is economy in generating steam at a pressure of 300 pounds, and admitting it to a quadruple expansion engine at a reduced pressure of 250 pounds per square inch, it would seem that the future general adoption of a water tube boiler with economizers is assured, and in the near future their consumption of fuel may be lowered to equal the Scotch boiler.

Sir John Durston shows that with economizers fitted to the Belleville boilers in the cruiser "Diadem," during a trial of thirty consecutive hours, when 12,813 horse-power was realized, the consumption of coal equalled 1.59 pounds per indicated horse-power per hour. This is nearly as low as in the fire-tube boilers.

The armament of the "Shikishima" consists generally of four 12-inch, fourteen 6-inch and thirty-two smaller guns. The ballistic data of the 12-inch guns is about as follows: Weight of projectile, 1000 pounds; initial velocity, 2234 feet; energy, 34,728 tons; perforating power, 25-inch steel.

The "Alabama," of our navy, and battleships of her class, are 368 feet x 72½ feet, and 11,525 tons displacement at 23½ feet draft of water.

Though these battleships are about 25 per cent. smaller than the Japanese or the large English ships, they may not prove to be at all less formidable fighting machines, as they will be more handy vessels and less liable to be held up by grounding. Moreover, though the guns of the main batteries are the same in num-

ber, our ships have four 13-inch guns, as against their four 12-inch, so that their perforating power should be about 20 per cent. greater than that of the foreign battleships.

The American cruisers engaged at Manila were armed only with 8 or 8¼-inch guns. Though these are much lighter than the big guns on our *battleships*, you will gather from the following that the 8¼-inch gun is a very formidable weapon.

Ballistic data of an 8¼-inch gun: Weight of projectile, 238 pounds; charge in pounds, 52; initial velocity in feet, 2336; energy in tons, 9012; range at elevation of 250°, 14,436 yards; perforating power through steel at 1100 yards, 15½ inches; length of gun, 24 feet; weight of gun, 14 tons.

American courage and skill at Manila would no doubt have secured a victory with very inferior ships, yet not without great loss of life and tonnage; but now it is clearly demonstrated that our ships were designed, constructed and armed so as to do great execution without ordinary exposure of the men to the destructive missiles of the enemy. These are ideal conditions in warship designs, yet they seem to exist to perfection in our new navy. But what we require in the immediate future is a number of larger armored cruisers with largely augmented fuel capacity. Only last month, in addition to the enormous government tonnage already building, the British Government contracted for four armored cruisers 440 feet long, 69½ feet broad and of 12,000 tons displacement at 26¼ feet draft; indicated horse-power 21,000, and speed not less than 21 knots. These are about 20 per cent. larger than our largest cruisers, but I trust that they may not very long be so.

The Spaniards do not make practical engineers. For several years I was assistant to the chief engineer of three lines of Spanish steamers, and, though all the officers and crew were Spaniards, the whole engine department was managed and worked by British engineers; and, as people of that nationality are certainly not loved by the Spaniards, it may be accepted as proof positive that the Spaniards were incapable of managing their own machinery, or they would never pay Scotch engineers two or three times as much salary as Spaniards would readily work for.

The incapacity of the Spaniards to stand up for any length of time before our ships is largely due to their ignorance and inefficiency as engineers. A modern battleship or large cruiser is nothing less than a complicated piece of machinery from keel to truck, in hull, armament and equipment. Imagine a hundred steam cylinders requiring half as much steam as the main engines to be kept in working order, besides numerous hydraulic and

electrical appliances, and you may acquire an idea of the mechanical skill necessary to keep a modern battleship in fighting condition.

Now there are plenty of grateful people in our community to praise the splendid gallantry of the commanders and sailors of our warships, but there is a class of men who are not so much seen on deck or on boarding expeditions, and whose names but seldom appear in the papers or in dispatches, but who, nevertheless, are doing as brave and noble a work as their weatherbeaten comrades of the bridge and deck. I refer, of course, to the engineers and their staff, and I may say, for I know it from personal acquaintance, that a finer class of men than our naval engineers are not to be found in any country. Many of them are good mathematicians as well as practical mechanics, and all are gentlemen; but engineers are not always treated as if they were. Sailors call them "the Black Squad," or "Sanguinary Blacksmiths," and I well remember the time, in the old country, when a great government marine department was always managed and under the control of a retired shipmaster, though the work to be performed was almost solely of a marine engineering character.

It was only a very few years ago that the position of principal officer was conferred by the British Government on George Carlisle, a marine engineer. Prior to that appointment the condition of engines, boilers, etc., on large steamers had to be approved and certified by a retired shipmaster. During the present struggle, while we "remember the Maine," let us not forget those brave men who keep up steam and work the machinery in the quietest manner possible, away from the glare of the sunshine and the ear of the scribe.

We are now on the last verge of a period rapidly vanishing away, and upon the brink of another period just as rapidly approaching. The present time is bristling with momentous possibilities, and it behooves us to give most earnest attention and thought to the opportunities now presenting themselves. It may be that the very existence of the Anglo-Saxon race, as a political factor in the economy of nations, is at stake. We cannot recede, "There is a tide in the affairs of men, which, taken at the flood, leads on to fortune." We are bound to go on with this righteous struggle, though it may have surprised some and though it disappoints others. The builder of our first monitors thought he had discovered the panacea for peace. Thirty-three years ago John Ericsson said: "The art of war, as I have always contended, is positively in its infancy; when perfected man will be forced to live

in peace with men. This glorious result, which has been the cherished dream of my life, will unquestionably be attained before the close of the present century."

The century is drawing to a close. Let us hope that Ericsson may prove a true prophet even yet, but his dream seems exceedingly far from realization.

It would now seem that we are more than likely to become an Oriental power, and we are also extending our possessions far South; but these possessions must be paid for, and a large item in the payment will be lives of our people. This is a new doctrine, of striking and vital import. What a marvelous change has come over us during the last few weeks. How different, in its tendency at least, from the celebrated "Monroe Doctrine;" strange that this was not foreseen! As we gain in resources we gain in power; as we gain in power we gain in influence, and our influence in the future must be important and far-reaching indeed. If the mechanical sciences and naval architecture arts of seventy-five years ago had stood still like "Joshua's moon in Ajalon" we might have remained in happy isolation from the sphere of European or Oriental influences, secure in the spirit of the Monroe Doctrine; but, with the advent of the screw steamer, the electric cable and the locomotive, space and time are annihilated and the nations farthest apart geographically are in closer touch to-day than England and Spain were in Monroe's day. In 1823, when that brilliant statesman enunciated his famous views of "hands off," or "America for Americans," there was not a screw steamer or a surface condenser on the ocean. Our total ship tonnage was less than one and a half million tons, the population of these United States was only eleven millions. To-day our population is nearly seventy-five millions, and our ships amount practically to five million tons. When one can leave the center of England on one Saturday and take midday lunch in Cleveland, Ohio, on the following Saturday, as I did last year, it may be truly said that "the seas but join the nations they divide."

How some of our prominent legislators, even a few months since, could talk of this free and most powerful nation continuing an isolated political existence with regard to the other great nations of the earth seems strange indeed, and I think that happy state is a condition of the past. If this is so, might it not be to our mutual advantage if an alliance could be cemented between the great Anglo-Saxon peoples, both far and nigh?

I think the people who have possession of Hong Kong, Australia, Gibraltar, Malta, Alexandria, Aden, Bermuda, Victoria

and a few other small possessions, such as India, Canada and South Africa, and which, politically and socially, are practically as free as any nation upon earth, should be worthy of an alliance with this great, glorious and all-powerful republic.

DISCUSSION.

MR. H. C. THOMPSON.—What is your opinion as to the relative values of the monitor and battleship as fighting machines.

MR. OLDHAM.—The distinguishing features of the monitor are that, requiring less steam radius, the armor can be heavier and the freeboard lower, so as not to present so large a target to the enemy. A battleship is higher, so as to be defensive against any weather, and its large coal capacity enables it to steam longer distances.

MR. JOHN N. COFFIN.—Has the theory of raising the water ballast above the gravity center been tested sufficiently to prove that the rolling is lessened thereby?

MR. OLDHAM.—The object of the design is to lessen the stability by lessening the righting moment. This is accomplished by raising the center of gravity to the metacentre, and so reducing the lever arm. The longer the righting lever the greater the moment to lift the vessel; and when she is lifted from one side she accumulates energy, passes the center and rolls to the other side, and then reaction follows. With less righting moment the reaction is less violent.

MR. W. C. PARMLEY.—At the present time we are all interested in battleships, and in the question not only of the efficiency of those we possess, but also of the correctness of the lines of our progress in the design of new battleships. The British Government, since 1890, has built about thirty first-class battleships. The earlier of these ships, of the "Royal Sovereign" type, were armed with 67-ton (13.5-inch) guns, were armored with 18-inch steel and had a speed of 16 knots. The ships of the "Majestic" and "Prince George" class, built about 1895, carry four 12-inch guns and 14-inch armor. The latest warships have decreased the armor to 12 inches and carry four 12-inch guns, with very heavy secondary and lighter batteries.

Our vessels started in with 13-inch and 8-inch guns, and with 18-inch armor. We have retained the 13-inch gun as the standard size for the primary battery, and retained an armor thickness of 16½ inches. In addition, we carry about the same number of rapid-fire guns as the latest British ships. The British ships are slightly faster than ours, and are of about one-third larger tonnage. Are

the British right in thus reducing the diameter of the heavy guns and the thickness of armor, or are we right in retaining the great weight and power of both?

Mr. Oldham.—The main difference is that the British vessels have greater coaling capacity than our ships, and their extra displacement is largely taken up in supporting the coal. I think the turret is a better protection for the gunner than the barbette, but there is more danger of its getting out of order. The steel of to-day is far stronger than that of a number of years ago. After a time we can abandon iron armor altogether, making the vessels in water-tight compartments and allowing the guns to go through them. By that means we can build two boats for every one, or three for two at least. All these questions rest very largely on a money basis. The British are now building ships because they have plenty of money. When hard times come the people will not stand it, and the work will have to stop.

Mr. Parmley.—What is your opinion of the relative fighting qualities of our "Alabama" class and the most formidable foreign vessels?

Mr. Oldham.—The most formidable foreign vessels have not yet been tried. I think we have the best fighting ships in the world. I think our ships, especially with a Dewey in command, could stand up against any of the British ships.

Mr. Searles.—We find ourselves very unexpectedly in the midst of foreign war. It hardly seemed credible at one time that it should be so, and yet the most momentous results may grow out of this condition. It seems to me the coming of age of this nation. We have been a lot of bright Yankee boys before, and now we are to take our part in the affairs of the world, which must be managed by some one. We must abandon our isolation, not from the spirit of ambition or vainglory, or the coveting of additional territory, but as a man coming of age must take part in the affairs of the world, so this nation must take part in the affairs around it. This throws the Monroe Doctrine to the winds, but it may become our national duty and privilege to assist in the direction of international questions.

In regard to the relative value of ships and armaments, it is my impression that more depends upon the men behind the gun than upon the gun itself. It is the discipline and spirit of the crew, rather than the amount of protection or the diameter of the bore. This naval conflict is a machine war, and it is not the best machines, but those operated by the best machinists and engineers, which are likely to win. On that account I feel very great confidence in the

ultimate success of our own arms. The Spaniard has very little genius for machinery, however great his personal bravery may be.

Mr. A. L. Hyde.—Our battleships and cruisers have been recently constructed, and yet we are constantly reading that they are smaller and carry less tons than those of other nations. Are our ships really less formidable, and, if so, why so? Is it a fact that our naval engineers have considered that smaller and speedier vessels are more formidable than some of the larger vessels? If we were to have a war with some other nation whose men behind the guns were the equals of our own, the contest would be decided by the superiority of the armor or of the guns.

Mr. Oldham.—The larger vessels will certainly be the more formidable, if they are as well constructed, designed and manned. The principal point is that the larger vessel can carry a larger supply of coal. I think our ships cost 30 per cent. more than British ships to construct. The question of dimensions is entirely an experimental one, and Sampson may have tried the experiment lately. The whole question of the formidability of battleships is yet to be solved.

Again, westerly winds prevail here, and we have not the heavy seas that they have on the other side of the Atlantic, so that we can get along with a lower freeboard. The British vessels must have height in order to get away from the waves, and I think that is the main reason that their vessels are larger.

Mr. Parmley.—How do you explain this fact: since 1890 the British have reduced the size of their most formidable guns from 13 to 12 inches, and the thickness of their armor from 18 to 12 inches, while we have kept our armament up to about 13 inches?

Mr. Oldham.—They have reduced the bore because they know that a shot from a 12-inch gun will go through any armor that exists.

Mr. Parmley.—Why should they decrease the thickness of the armor?

Mr. Oldham.—Because the steel is far stronger than it was.

Mr. Parmley.—Then why should we keep it up?

Mr. Oldham.—Because we have to carry less coal, and can put the weight into the sides of the vessel. I think you will find that we shall be building battleships of 15,000 tons. The tendency is toward lighter armor and greater speed. I think the armor is not of so much importance; Dewey has not an armored ship with him.

Editors reprinting articles from this journal are requested to credit both the JOURNAL and the Society before which such articles were read.

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ABOLITION OF THE GRADE CROSSINGS ON THE MAIN LINE OF THE BOSTON & ALBANY RAILROAD IN NEWTON, MASS.

BY IRVING T. FARNHAM, WILLIAM PARKER AND W. G. S. CHAMBERLAIN. MEMBERS OF THE BOSTON SOCIETY OF CIVIL ENGINEERS.

[Read before the Society, February 16, 1898.*]

I. History of the Improvement, and an Account of the Street and Drainage Work Connected Therewith.

BY IRVING T. FARNHAM.

FOR several years the abolition of the grade crossings in the city of Newton has been a subject of agitation among the citizens and taxpayers. The city covers a large area in proportion to its population, and consequently has an unusual mileage of railroad, mostly controlled by the Boston and Albany Railroad corporation. The four tracks of this road extend through the city from the village of Newton to Riverside, a distance of 4.4 miles. At Riverside two tracks branch to the south, returning to Boston through Eliot, Waban, Newton Highlands, Newton Centre and Chestnut Hill, making altogether 1 mile of single, 6 miles of double track road and 4.4 miles with four tracks.

Only the crossings on the north side of the city on the main line have been abolished. There were thirteen of these, two of which were private streets, but were provided for with the rest; and

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two (St. James street and Bellevue street) already crossed on overhead bridges, but had to be changed to fit the new conditions of grade. The city has also built four new streets, crossing the railroad, making a total of seventeen crossings, one having been discontinued.

The two north tracks of the railroad are used for the through traffic, while the south tracks are for suburban travel. At each of the stations of Newton and Newtonville there was a grade crossing, while at West Newton Station there were two grade crossings in close proximity to the station. Persons hurrying to and from the suburban trains were in constant danger from the expresses on the north tracks, and the greatest care of gate tenders could not avert disaster. There seemed to be no question of the necessity of separating the railroad and street grades, but how it could be accomplished to give the best results, both for the city and the railroad, was the problem. No expense was spared to give the matter a thorough study, both as to its engineering and economic features.

The State Commission of Engineers, appointed in 1888 to report upon the "gradual abolition of the crossings of highways by railroads at grade," with suggestions and recommendations as to the best method of accomplishing such abolition, reported in 1889 upon the crossings in Newton and other cities, and recommended a plan for abolishing the crossings by depressing the tracks from east of St. James street to a point between Mt. Vernon street and Greenwood avenue, and elevating the remaining distance to Auburn street, Auburndale, carrying the streets over and under in each case. Their plan did not, of course, go much into detail, except to establish a proposed grade shown on a profile with the report. On this profile is also marked a grade for depressing the track the entire distance, which was proposed by our esteemed associate, the late Mr. Noyes, who was then City Engineer. This plan called for a large change in the railroad grade, with slight changes in the streets, and seemed too bold to meet the approval of the commission. To quote from their report: "By Mr. Noyes's plan, the principal work in separating the grades will be on the railroad. Only a few unimportant changes are proposed in the streets. The question of proper drainage for a long railroad cut, as proposed by this plan, is one that should be carefully considered. To sink the railroad to a depth recommended will not only be expensive, but there is also an uncertainty, in our opinion, as to the results that will be obtained from the system of drainage recommended. The question of proper drainage for a railroad of such magnitude as the Boston and Albany is a matter of vital import-

ance, and a plan should be selected that would secure it beyond a doubt." Other seemingly good objections to this plan raised by the commissioners were the extra expense, the delay in traffic and the heavy rock-cutting that would be encountered. Most of these difficulties, however, as will be shown, were avoided in the final plan for depressing the tracks.

In 1892 a commission of engineers, consisting of Messrs. Albert F. Noyes, City Engineer, George S. Rice and Charles A. Allen, all members of this Society, was appointed by the city government to make plans, with estimate of cost, for the abolition of the grade crossings. First, by depressing the tracks and elevating the streets; second, by elevating the tracks and depressing the streets; third and fourth, by carrying the railroad north on a new location, through a less thickly populated district. This commission reported in May, 1893, recommending that the tracks be elevated on the present location. The relocation through a different section of the city was discarded as impracticable, because of the radical changes in property valuation which would result. This could not be estimated in dollars and cents, but would undoubtedly work great hardship and severe loss in the one case, while it would immediately benefit land-owners in other cases.

After the receipt of this report hearings were given by the city government for the expression of public opinion upon the plan of action. Notwithstanding the report, the general feeling seemed to be in opposition to a railroad embankment through the city, and, as the railroad officials were not ready to co-operate with the city for depressing the tracks under the existing laws, it was decided to defer the improvement until more favorable legislation could be obtained.

Washington street is the main highway through the north part of Newton, and runs parallel with and in close proximity to the railroad from Newton to West Newton, $2\frac{1}{4}$ miles. It is the main thoroughfare between Wellesley and Weston, on the west, and Watertown, Cambridge and Boston on the east, and for some time there had been a demand for widening this street. The width of the old street varied from 37 to 60 feet, and both sides were closely built up through the villages of Newton, Newtonville and West Newton, making it necessary to move or destroy a large number of buildings to widen the street on either side; while on the south side of the street the lots between the street and the railroad were shallow, which made expensive any widening of the street on this side or the acquiring of land from the rear of these lots for sloping purposes in depressing the tracks.

By combining the two improvements the lots on the south side could be utilized, and an act was obtained from the Legislature in 1895 allowing the city to take land for "widening Washington street and abolishing grade crossings" over and above what was absolutely necessary for the work, and to dispose of any remaining land, after the work was completed, that the city deemed proper.

Under the new act nearly all the land between Washington street and the railroad from Newton to West Newton was seized. This made possible the depressing of the tracks with a broad open cut, and the widening of Washington street to a width of 75 and 85 feet, a much needed improvement. This combined improvement necessitated the destruction or removal to other locations of three brick blocks, twenty-two wooden blocks and seventy-one dwellings. The total expense of acquiring this property was about $573,000.

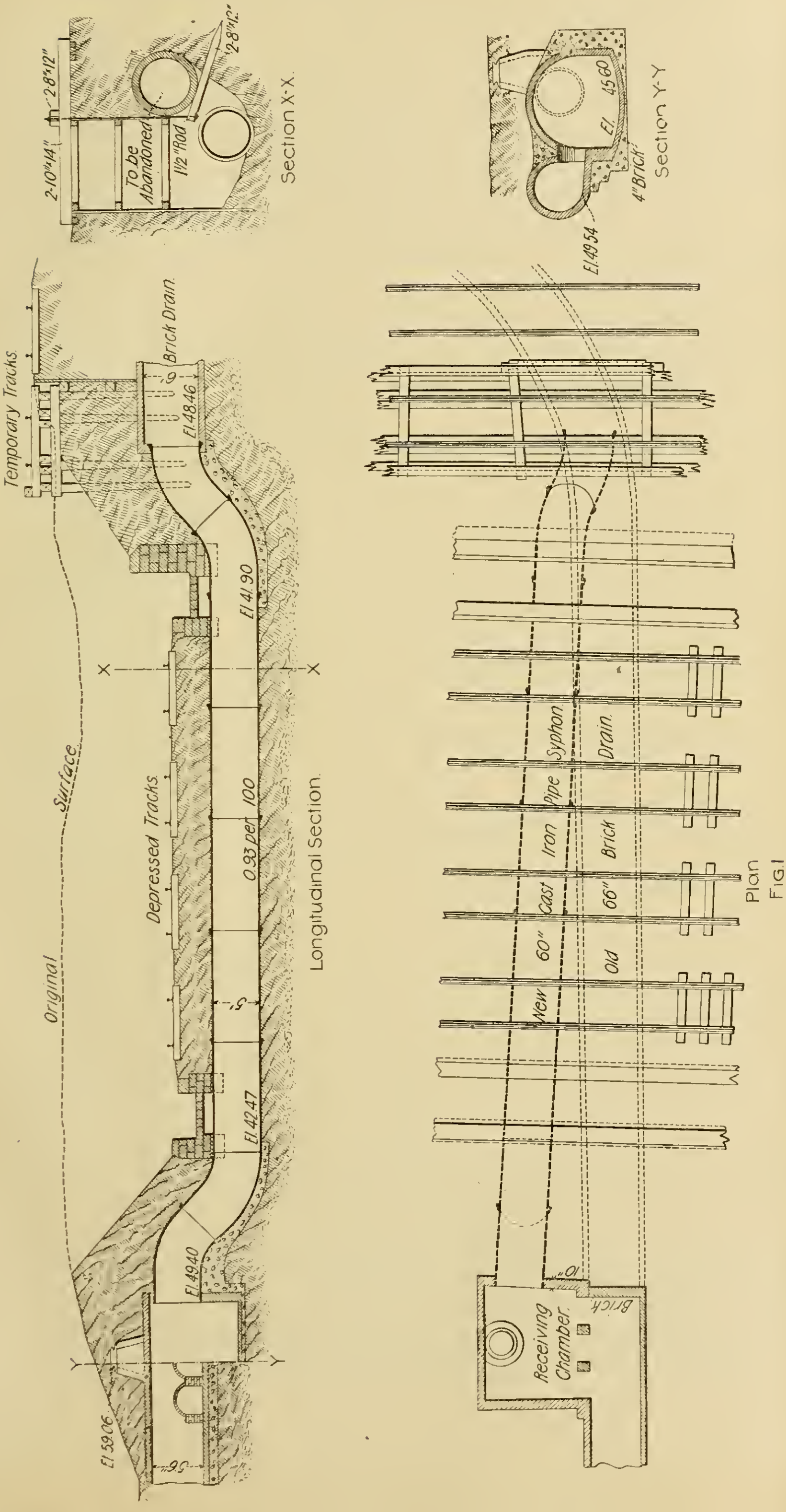
In the final decree of the court the division of cost was made according to the general act on grade crossing; that is, the railroad pays 65 per cent., the city 10 per cent. and the State 25 per cent. of the accounts, as approved by the auditor appointed by the court.

As many changes had to be made in the line and grade of existing brooks, drains and sewers, the decree of the court included the necessary land takings for new locations and widening existing brooks. Another feature of the decree is that portion which refers to rights to slope the filling beyond the limits of the street. The wording is as follows:

"The filling may be sloped beyond the limits of said street so far as may be necessary to hold the embankment, and for this purpose the rights and easement to enter upon the following parcel of land, to construct and maintain the necessary slopes thereon, is hereby taken. Said parcel is bounded and described as follows."

Then follows a description of the parcel of land between the street and the proposed foot of slope, described by offsets and distances from the street line. These were figured for a two to one slope, allowing one foot berm.

Frequent inquiries have been made of late in regard to this. No objections can be recalled as having been brought in the settlements in Newton for grade damages by this matter. But there seems to have been considerable trouble caused by taking rights to slope in other city work, not only in Newton, but, as the writer understands it, also in Boston and other places. The trouble seems to be in getting a wording which will confer the privilege desired by the city of supporting the sides of the street by slopes, without going to the expense of retaining walls, and yet not take



Longitudinal Section and Plan, Worcester Street Siphon.

from the abutting owner any of his rights to use his land as he may desire, provided he does not interfere with the street or endanger its existence. If he desires, he can substitute a retaining wall for the earth slope, using proper precaution of shoring while the work is in progress, and thus be able to build clear up to the street line.

The city does not desire to own any land back of the street line, but only to maintain that line at the proper grade. It would seem as if a proper form might be devised covering this point which would hold in court.

In establishing the new grades for railroad and streets the controlling feature was the drainage. The tracks were put to a grade as low as possible, all available fall in the three brooks crossing the railroad being utilized; and channels for these three streams were constructed to give an hydraulic grade line during flood flow only 5 feet above the grade of bottom, which necessitated widths of 10, 12 and 16 feet.

The grade of the streets at the bridges was determined by the 16 feet clear head-room allowed by the Railroad Commissioners, to which was added $1\frac{1}{2}$ feet for solid bridge floor, making the street grade about $17\frac{1}{2}$ feet above the grade of the rails. The rates of the street grades at the approaches to the bridges were governed largely by the item of damages to the adjacent property and buildings, and varied, with three exceptions, from 2.87 to 5 per cent. The three exceptions were Lewis Terrace, Mt. Vernon street and Felton street, which were carried up from Washington street to the bridge by a rate of 6, 6.50 and 7.50 feet per 100, these steeper rates being warranted by the old grade on the south side of the tracks, where the street ascended the hill at rates exceeding those mentioned.

The grade of Washington street was raised at its intersection with Walnut, Harvard and Church streets, to meet the new grades of these streets. The maximum change of street elevation was $7\frac{1}{2}$ feet at the Washington street crossing (West Newton), the minimum change being at Centre street, Newton, which was raised only one foot. St. James street, which originally crossed the railroad on a bridge with an ascending grade on either side, was lowered 4 feet at the railroad, to give nearly a straight grade from its intersection with Orchard street, on the north side of the railroad, to its intersection with Hunnewell Terrace, on the south side. The street will now be carried over the depressed tracks on a deck bridge, there being ample room between the tracks and the street grade for such a structure.

Bellevue street formerly crossed the tracks on a bridge with a

descending grade. Turning sharply to the east, the street descended at a 6.60 per cent. rate to Washington street. Under the new conditions, with Washington street widened on the south side at this point and the tracks moved north, there was no space for approaches to the bridge from Washington street, so this crossing was abolished, and Bellevue street was carried easterly on a new location, south of the Boston and Albany Railroad, along the top of the railroad slope to connect with Church street near the railroad crossing. This new section of Bellevue street is about 1280 feet long, and was built with the necessary sewers and drains. A new crossing was also made at Lewis Terrace, just west of the old Bellevue street crossing, the expenses of the approaches being entirely born by the city.

By a special act passed in 1896, the city of Newton and the Albany Railroad were authorized to include in any petition for abolishing grade crossings not only all public ways, but also all private ways which might exist across the railroad. Under the provisions of this act several crossings which had never been made public were changed, and in one case, Greenwood avenue, was discontinued and a substitute placed at a different point. Also several new crossings were included in the act, one which replaced a footway under the track at Centre Place, and one at Richardson street, where a crossing had existed before the railroad was widened to four tracks.

It was under the provisions of this act that Austin street, on the south side of the track, was extended westerly from Greenwood avenue to Hillside road, West Newton, as it was impossible to have a raised crossing at Greenwood avenue, owing to the proximity of Washington street to the railroad. A new crossing had to be substituted for Greenwood avenue at Felton street, some 530 feet to the west, near the location of an old right of way which had not been used for many years, but where a gate existed in the railroad fence. This extension of Austin street was found necessary to give access to the new crossing at Felton street to parties who had previously used Greenwood avenue.

The changes in street grades, as well as in the drains and sewers, were made by the city forces, under the supervision of the City Engineer and Superintendent of Streets.

The changes in the sewers and drainage system were of considerable magnitude, necessitating the lowering of 4300 feet of sewer and the construction of two inverted sewer siphons. Of the storm-water drains there were constructed or relaid 4870 feet of brick drain, varying in size from 30 to 51 inches, and one inverted

siphon 5 feet in diameter, besides 3720 feet of pipe drain. The change in grade of the brooks extended over a total distance of 1.2 miles, of which 4830 feet were of the covered or closed section.

Hyde Brook, which crosses the tracks diagonally at Washington street, Newton, was the first to be lowered. This brook has a drainage area of 357 acres, and was constructed for a flood

TABLE SHOWING CHANGES IN DEPRESSION OF BOSTON & ALBANY TRACKS THROUGH NEWTON.

Street Crossing.	Street raised.	Tracks low'r'd.	Bridges. Width.	Bridges. Length	Bridge Seat.	Height Truss or Girder.	Roadway.	Sidewalks.
Com'w'lth Av.,	18.50	....	80 ft.	72.57	67.79	9′-0″	2–30′.00	7 ft.
Washington St.,	7.80	10.20	85 ft.	109.92	102.97	17′-4″	2–21′.00 21.50	7 ft.
Putnam St ,	5.00	10.85	40 ft.	67.33	61.46	8′-6″	25.00	6 ft.
Chestnut St.,	6.10	11.40	49.50	67.33	61.46	8′-6″	30.00	8 ft.
Highland St ,	6.00	11.85	42 ft.	67.33	61.27	8′-2″	25.00	6′-10″
Felton St.,	8.15	10 00	40.00	67.33	61 46	8′-6″	25.00	6 ft.
Mt. Vernon St.,	7.34	10.45	40.00	67.33	61.47	8′-6″	25.00	6 ft.
Appleton St.,	5.13	12.60	50.00	74.00	68.45	9′-0″	30.00	8′-4″
Walnut St.,	3.81	14.17	100.00	67.33	61.47	9′-0″	2–34.00	12′
Harvard St.,	5.14	12.74	40.00	67.33	61.46	8′-2″	25.00	6 ft.
Lewis Terrace,	6.16	12.20	40 00	71.67	66.00	9′-0″	25.00	6 ft.
Church St.,	4.60	13.00	50.00	72.42	67.02	9′-0″	30.00	8′-4″
Richardson St.,	3.92	13.75	40.00	67.33	61.46	8′-6″	25.00	6 ft.
Centre Place,	2.91	14.86	40 00	67.33	61 46	8′-6″	25.00	6 ft.
Centre St.,	1.44	16.35	71.00	102.42	93.77	20′-3″	2–23′-4″	9 ft.
Washington St.,	1.69	16.45	77.00	89.33	82.55	9′-0″	2–26.00	9 ft.
St. James St.,	*4.50	14.10	30.00	....	....	....	20.00	5 ft.

*Lowered.

Total length of change in grade of railroad........19,300 feet, or 3⅔ miles.
Grass slopes on both sides for.....................12,885 "
Grass slopes one side, wall opposite............... 4,695 "
Walls on both sides............................ 1,720 "

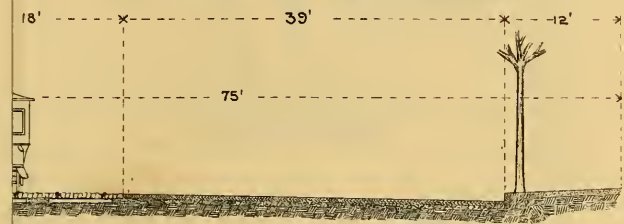
19,300 "

Walls over 6 feet on both sides.................... 660 "
" " " on north side only.............. 3,160 "
" " " on south side only.............. 1,658 "

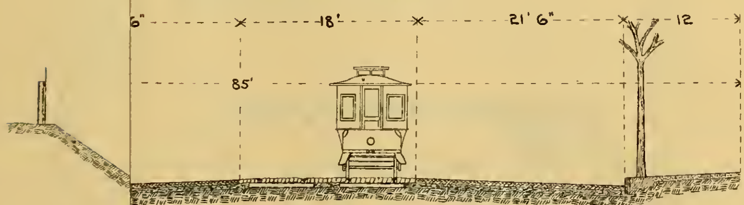
discharge of 714 cubic feet per second, which, on a 6-10 rate, required an effective area of 50 square feet. In order to pass under the depressed tracks it was necessary to lower the bed of this brook 17 feet; and to clear the bridge abutments a new location was taken, crossing the tracks at right angles west of Washington street bridge, Newton, passing through Washington street and Charlesbank road to connect with the drop manhole in the old brook in private land about 390 feet from the railroad.

NS STREET.

WASHINGTON STREET.



WASHINGTON STREET.



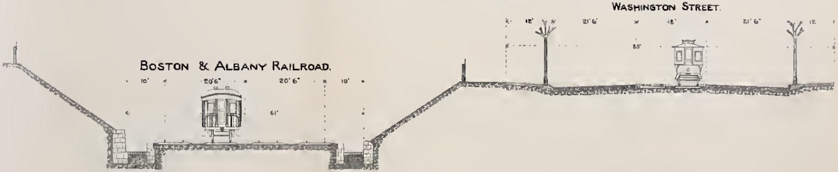
F

ASHINGTON ST.

95.

Section at Parsons Street.

Section West of Walnut Street.



Cross Sections of
Boston & Albany R.R. and Washington St.

Newton, Mass. Dec 1895

0 5 10 15 20

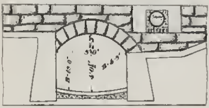
Scale of Feet

0 1 2 3 4 5 6 7 8

Scale of Metres.

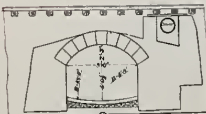
Geo. H. Walker & Co. Lith. Boston

SECTIONS—SCALE



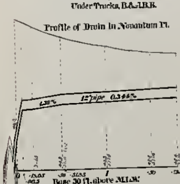
At North Gutter, B.A.R.R.

Sta.9-54 to 13 45.6
and 15-12 to 17-50

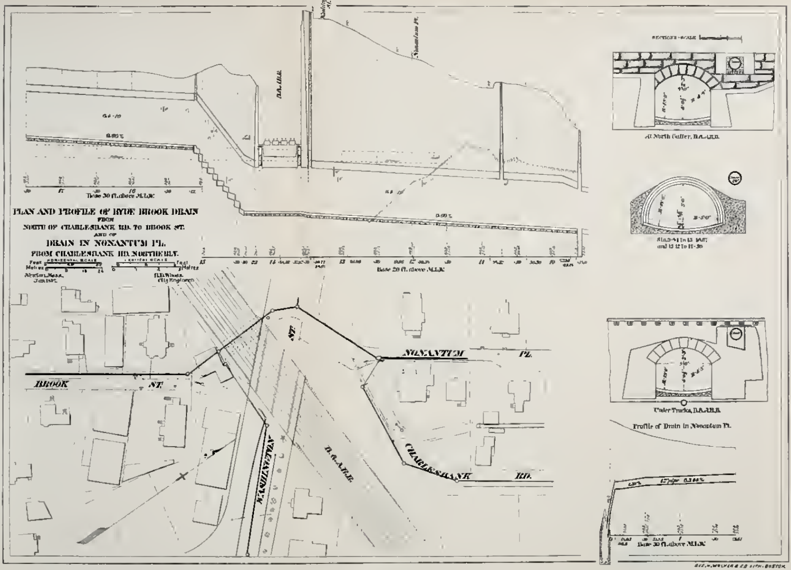


Under Tracks, B.A.R.R.

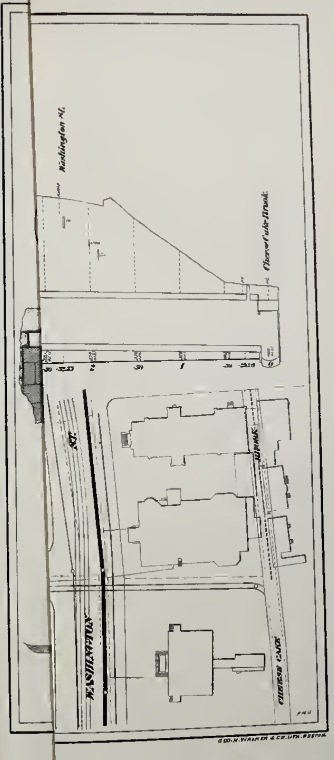
Profile of Drain in Nonantum Pl.

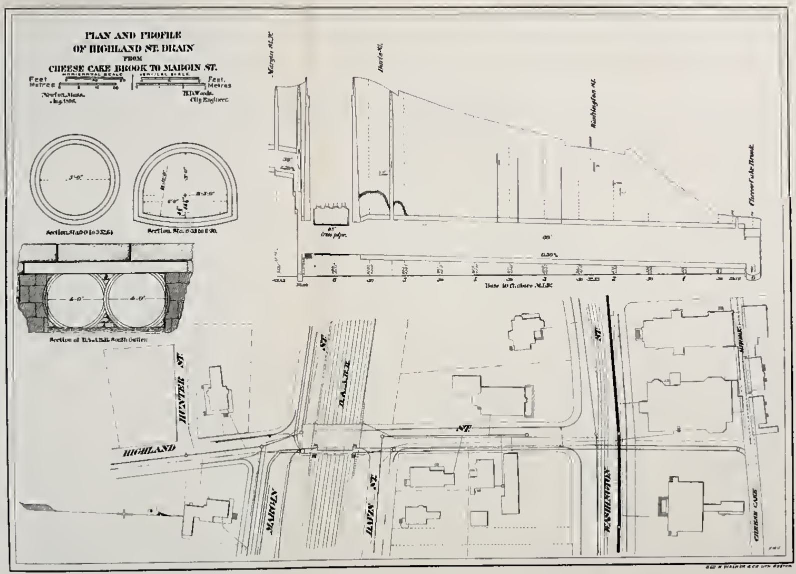


GEO. H. WALKER & CO. LITH. BOSTON.


PLAN AND PROFILE OF HYDE BROOK DRAIN
FROM
NORTH OF CHARLESBANK RD. TO BROOK ST.
AND OF
DRAIN IN NONANTUM PL.
FROM CHARLESBANK RD. NORTHERLY.
Base 30 ft. above M.L.W.
Base 20 ft. above M.L.W.
BROOK ST.
NONANTUM PL.
WASHINGTON ST.
CHARLESBANK RD.
B.&A.R.R.
At North Gutter, B.&A.R.R.
Under Tracks, B.&A.R.R.
Profile of Drain in Nonantum Pl.

FARNHAM.—NEWTON GRADE CROSSING.




PLAN AND PROFILE
OF HIGHLAND ST. DRAIN
FROM
CHEESE CAKE BROOK TO MARBIN ST.
Feet
Metres
Newton, Mass.
Aug. 1896.
H. D. Woods,
City Engineer.
Section, Sta. 0+0 to 3+32.6
Section, Sta. 0+33 to 8+30.
Section of B. & A. R.R. South Gutter
HIGHLAND
ST.
HUNTER ST.
MARBIN
DAVIS ST.
WASHINGTON ST.
CHEESE CAKE
Base 10 ft. above M.L.W.
Davis St.
Kinsington St.
Cheese Cake Brook
Iron pipe

The section adopted was a semicircular brick arch of 5-foot radius, with a flattened invert, which, with the water flowing 5 feet in depth, gives the necessary area of discharge. The alignment of this brook was necessarily quite indirect, the turns being constructed on curves of 40-foot radius. About 200 feet of 20-inch sewer was also relocated and built on the haunch of the arch in the same trench. The portion of this drain under the tracks was built with a stone arch by the railroad forces. On the south side of the tracks the brook was brought up to the regular grade at Brooks street by a series of granite steps. The cost of constructing this brook, with an average cut of 20½ feet, including the excavation of 1400 cubic yards of rock, was about $35 per running foot.

The second stream to be lowered was Laundry Brook, which crosses the tracks between Newton and Newtonville. This brook is formed by the junction of Hammond and Cold Spring Brooks, and drains a water shed of 2800 acres south of the railroad tracks. The plans for future development of this brook and the city drains tributary thereto requires a capacity for a discharge of 860 cubic feet per second, which, with the available grade of 36-100, calls for an area of discharge of 71 square feet. To obtain this, with the available head-room under the depressed tracks, which was only 5 feet, it was necessary to make a channel 16 feet broad.

The brook, after leaving the railroad, crosses Washington street, flowing for a short distance through developed property, whence it meanders through low lands with low side walls to the Charles River. The depression of the tracks made it necessary to lower the channel at the railroad 5 feet, to gain which the grade was changed from Pearl street to the railroad, a distance of 2500 feet.

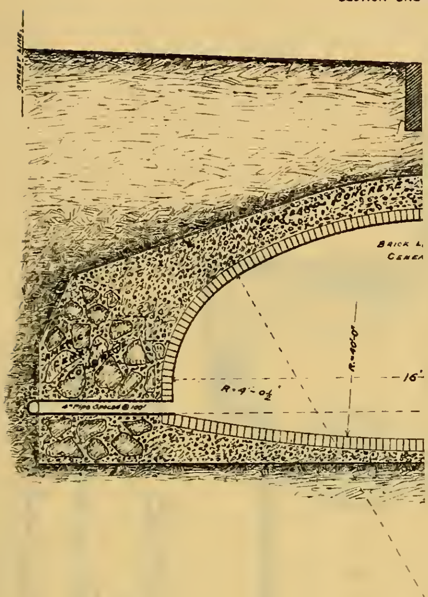
Beginning at Pearl street, the brook was carried on a new location in an open channel with grassed slopes, through the low land, a distance of 1160 feet, or 183 feet shorter than the old winding stream. The channel was constructed with paved bottom and low side walls, from which the banks rise on a three to one slope. Through the higher land an open brook meant side walls of excessive height or a large area for sloping purposes, necessitating heavy damages. To avoid this item of large damages the brook was carried in a closed culvert, similar to that constructed under the streets. This was a concrete arch with side walls one foot high and a flat invert, the whole lined with one course of brick. On account of the wide span and the limited head-room over portions of the arch, it was built as flat as practicable, the basket-handle type being

adopted, with a radius of 12 feet for the middle portion, connected on the sides with curves of 4 feet radius. The brick was laid in Portland cement, mixed one and one-half to one. American cement concrete was used in the invert and on the sides, where it was stepped off to receive the Portland concrete of the arch proper. The concrete in the arch was made from the best English Portland cement, thoroughly tested, and was mixed in the proportion of one, three, four. The thickness of concrete at the crown was 12 inches, making, with the brickwork, a total thickness of 16 inches at the crown of the arch under the street surface. This was reduced to 12 inches in the private land, where the covering was light. A plastering of Portland cement $\frac{1}{2}$ inch thick was carried over the whole, and where the concrete came so near the surface as to be effected by frost the arch was coated with a wash of tar and asphalt, to exclude the moisture.

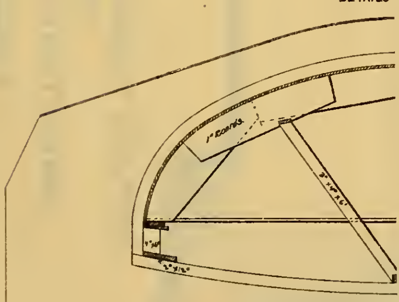
Layers of stone from 4 to 12 inches diameter were laid in the side walls, around which the concrete was rammed. This added to the weight and reduced the amount of concrete. The concrete was rammed in place in 6-inch layers, care being taken to get good bond between the layers and keep the whole as near homogeneous as possible. On the sides where sheathing plank were required the concrete was filled in solid against the planking, which was cut off above the concrete and left in place. The centers for this work were built in 10-foot sections of two pieces each, joined at the crown and braced as shown. To build around the curves special curved centers were made, with a radius of curvature of 40 feet on the center line. There was constructed 1365 feet of this form of brook, about half of which is under the street. The cost, exclusive of the land damages, was $28.75 per foot, the masonry alone costing $18.76. The culvert for this brook underneath the tracks consists of three lines of cast iron pipe 5 feet in diameter, which was laid in 12-foot lengths, supported at each end on masonry piers. The joints were made tight with cement mortar, and the space between the pipes was filled with concrete.

The change of grade of Cheese Cake Brook, at West Newton, was the most expensive of the brook changes for depressing the tracks. This brook has a drainage area of 826 acres south of the Boston and Albany tracks, and, after crossing the tracks, it flows through a closely built section for some distance. One factory and many other buildings have been built close to the side of the brook, in some cases the brook wall forming the foundation for one side of the adjacent building. Under these conditions, any change in the brook meant heavy expenditures for construction as

SECTION UND



DETAILS



LAUNDRY

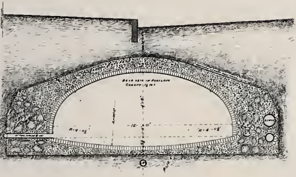
SCALE

NEWTON, MASS.,
MAY 1896.

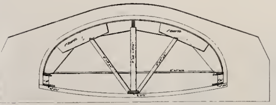
SCALE

Geo.H.Walker

SECTION UNDER WASHINGTON ST.



DETAILS OF CENTRES.



LAUNDRY BROOK DRAIN.

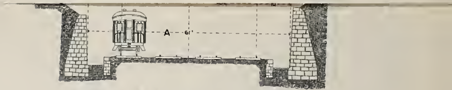
SCALE OF FEET

NEWTON, MASS., MAY 1894.

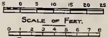
SCALE OF METRES

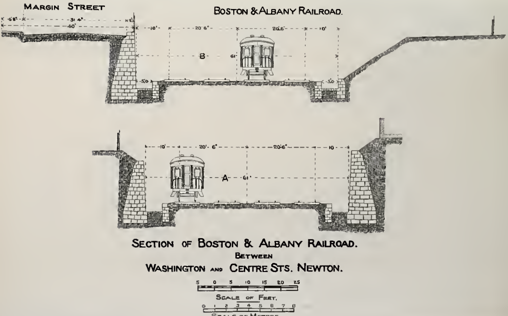
H. D. WOODS, CITY ENGINEER.

Geo. H. Walker & Co. Lith. Boston.



SECTION OF BOSTON & ALBANY RAILROAD.
BETWEEN
WASHINGTON AND CENTRE STS. NEWTON.





SECTION OF BOSTON & ALBANY RAILROAD.
BETWEEN
WASHINGTON AND CENTRE STS. NEWTON.

Geo H Walker & Co. Lith Boston.

well as for damages. The damage question for a long section which was closely built up was settled by an arrangement with the property owners, by which the brook should be covered over. By covering the channel the abutting properties were at once relieved from the nuisance of an open drain into which all manner of filth and refuse had been dumped, despite the police and health officers, and the appearance of this part of the city was greatly improved.

It was necessary to lower this brook 5.8 feet at the railroad, and to accomplish this the whole line of brook from Germain street to the railroad, a distance of 3260 feet, was lowered. The rate of grade for most of the distance was only 16-100 per hundred. This low rate, with the limited head-room at the crossings, required a widening of the channel from 8 to 12 feet. But this widened channel is not equal to the discharge of the water from the branch of this brook which enters north of the railroad, it being proposed to cut a channel northerly to the Charles River for the discharge of this branch brook whenever the capacity of the present channel is exceeded.

The new channel was built with vertical side walls, which extended one foot below grade, and were built to the surface, or $5\frac{1}{2}$ feet high, where the brook is covered, which gives an area of discharge of 60 square feet with $\frac{1}{2}$ foot clear space from top of water to bottom of covering.

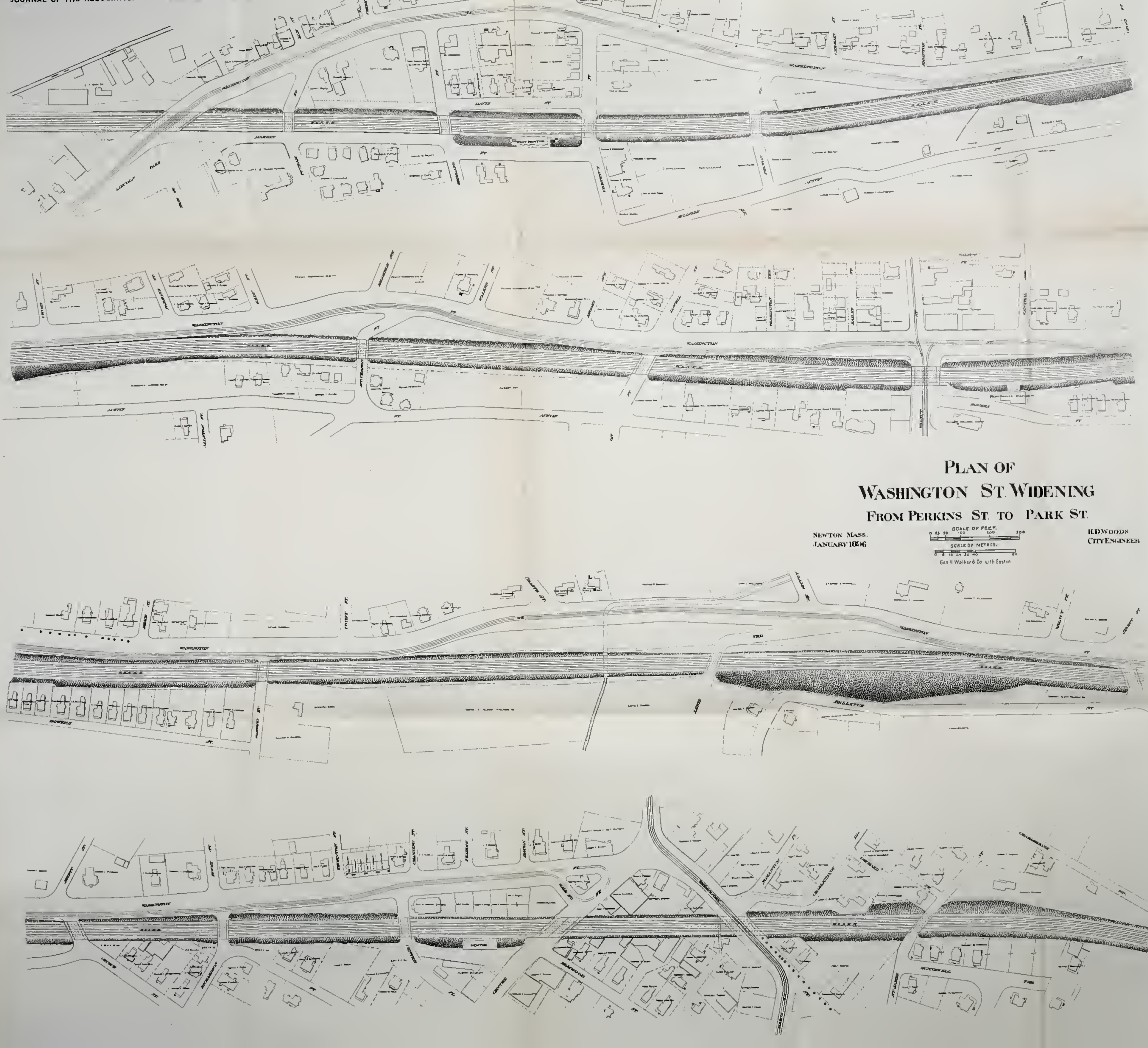
There were six streets crossing this section of the brook. At these crossings steel and masonry bridges were constructed of 10-inch I beams, weighing 30 pounds per foot, spaced 2 feet 11 inches and arched with 4-inch brick arches, covered with Portland concrete to a depth of about 6 inches above the I beams. The surface of the concrete was given a slope of 2 inches from the center of the brook to the sides, and the whole surface, after being plastered with Portland cement plaster, was coated with a mixture of asphalt, pitch and tar, mixed in the proportion of five barrels of coal tar to three barrels of Trinidad asphalt. In turning the arches special molded brick, made from patterns, were used to fit the flange of the I beam at the springing line. These bricks cost about double the price of the ordinary brick, but saved the extra cost in brick that would have been broken and wasted, and the labor of cutting, besides giving much stronger and neater work. The ends of these culverts, where exposed, were finished by a cut-granite face stone, and a retaining wall to hold the street filling in place. This same method of covering with 8-inch I beams was used in private land. The remaining covering for brook, where there was very light filling and no chance for a load to come on the center, was made of

granite covering stones varying from 10 to 14 inches in thickness.

The brooks being lowered, the six storm-water drains crossing the railroad, with the exception of the Worcester street drain, could be lowered below the tracks and discharge by a straight grade into the brooks. The Worcester street drain could not be so disposed of. It consisted of a $5\frac{1}{2}$-foot circular brick channel, and the grade of the depressed tracks required a lowering of 7 feet. By making a summit in the grade of the railroad gutter, near this point, no outlet was required for the drainage of the railroad; so that it was possible to carry the drain beneath the depressed tracks under pressure, returning to the original drain grade on the north side of the tracks. This was accomplished by using 60-inch cast iron pipe laid in 12-foot lengths, joints calked with lead. The change of direction at each end was made by using two special eighth bends. The pipe weighed from 15,500 to 16,700 pounds each, and were handled with the same derrick used for hoisting the material excavated from the trench. This derrick was well stayed with eight guys, and in handling the pipe triple blocks were exchanged for the single blocks used in excavating.

To avoid breaking into the old drain during construction, which would have meant flooding the work during every storm flow, the line of the siphon was offset 10 feet to the west at the south or upper end, the intervening space being occupied by a chamber constructed to serve as a settling basin. From this chamber the line converged to meet the old drain line on the north side of the track. By this means the bends on the south side and three of the straight pipes could be laid without undermining the brickwork of the old drain. For the remaining distance the drain was undermined, being supported by cross-pieces driven well into the side of the cut, and braced from the bottom on one end and suspended by $1\frac{1}{2}$-inch tie rods at the end projecting into the trench. These tie rods were run through long cross-pieces at the surface, and threaded at the upper end so that a suitable tension could be given to the rod before the earth was excavated from under the drain. These rods were in the line of the sheeting, which was driven so as to fit closely against the side of the old drain to prevent any lateral movement. The cut for this work was largely in loose embankment, and close to the original drain trench, requiring extra care in sheathing and bracing.

The main cross-braces were spaced a little more than 12 feet, the length of the pipes, apart. As a precautionary measure, intermediate braces were loosely driven in place, which could be removed from each section while lowering a pipe. To place the last



PLAN OF WASHINGTON ST. WIDENING FROM PERKINS ST. TO PARK ST.

NEWTON MASS.
JANUARY 1896

H. D. WOODS
CITY ENGINEER

two special pipe the brick wall was broken out, and the final connection with the drain on the north side was made under the trestle of the temporary railroad tracks on Sunday, while the trains were running on the opposite track. The total cost of this siphon, including the cost of the iron pipe, was $5110. The joints took 120 pounds of lead each, and cost $13 per joint.

The original plans for separating the grades, as submitted to the Grade Crossing Commission, called for no lowering of the West Newton Station. The descenet of 14 feet from the station to the platform was to be made by a flight of some twenty steps at each end of the station. The patrons of the railroad, residents of West Newton, felt that this climb would be somewhat of a hardship, especially to the elderly passengers daily taking the train, and in June, 1897, the City Engineer submitted plans to the railroad for depressing the north portion of Margin street and the station 10 feet. These plans were accepted by the railroad on condition that the city would bear all the expense of changing the street. These conditions were accepted, and accordingly a contract was let for lowering the north portion of the street and building a retaining wall to support the upper Margin street. The width of the original street was 50 feet; this was widened by taking 4 feet from the railroad sidewalk. This gave an upper sidewalk of 6 feet 8 inches and roadway of 25 feet 4 inches, and a lower roadway of 21 feet in clear width, one foot being taken for the fence and batter of retaining wall. The distance from Chestnut street, on the east, to Highland street, on the west, was 500 feet. The grades of both these streets being fixed by the bridges, it was necessary to make the grade of the depressed street at the approaches on either side of the station on a 9-foot per 100, in order to allow a level space for carriage stand. The expense of this change in street was $4368, which was well warranted by the added convenience to the West Newton passengers.

Nearly all the changes incidental to the widening of Washington street and the separation of grades are now completed, and cost the city to date $962,600. Of this amount, $713,742.40 is the cost of widening Washington street, of which but $125,000 was for construction, the rest being for damages. The city has spent on the work connected with grade crossings, for construction, $313,339.42; for damages, $108,014.75; total, $421,354.17. Of this amount, $373,199.74 has been allowed by the auditor as a portion of the grade crossing accounts, and has been repaid by the State, the remainder being wholly chargeable to the city for approaches to new bridges, etc., as also $4378.47 for the depression of Margin

street at the West Newton Station, which was not included in the original plan.

The city's share of the total cost of grade crossing, as ordered by the decree of the court, up to January, 1898, is $196,362.79, or 1-10 of the total expense to date. This amount the city will repay the State in various annual instalments.

The difference in the appearance of the portion of the city through which the tracks have been depressed, and Washington street widened, is much more apparent to casual passengers than to those who have watched the daily changes during the two years of construction, and, although there was considerable criticism when the work was begun, there are now many expressions of approval and the general feeling is one of satisfaction.

II. The Depression of the Railroad Tracks.

By William Parker.

The portion of the Boston and Albany Railroad affected by the work of separation of railroad and street grades, recently completed in the city of Newton, lies between the sixth mile-post, a few hundred feet west of Faneuil Station, and a point about one-half mile east of Auburndale Station, a total distance of 3.65 miles.

Commonwealth avenue crossing, formerly Rowe street, is about 1000 feet west of the point where the depression of the railroad ends. The separation here was accomplished wholly by raising the street.

The distance from Boston to Riverside, on the main line, is 10.7 miles. The total distance from Boston to Boston by the circular route is 22.9 miles.

Most of the trains bound for points on the main line beyond Riverside are express to Riverside.

The main line has four tracks, the two northerly tracks being for express passenger trains and freight trains, and the southerly two for local passenger trains. The Newton Highlands branch and the Circuit are double track, and the Lower Falls branch single track.

Previous to the separation of grades there were nine highway and two private crossings at grade on the main line.

In July, 1895, six months previous to the appointment, by the Superior Court, of the commission to consider the separation of

grades, 153 trains passed over this section of the road daily. Of these, 76 were local passenger trains, 50 express trains and 27 freight trains.

It may be of interest here to note the manner in which these conditions gradually came to exist,—conditions which, in connection with the grade crossing question, called for so much careful and prolonged consideration and discussion, and the changing of which has required the expenditure of large sums of money.

In the 1837 report of the Boston and Worcester Railroad Corporation we find the following: "Passenger trains make two trips each way daily through the year, and during the summer months three trips, stopping at ten places between Boston and Worcester. Freight trains usually make one or more trips each way daily." Quoting further from the report, we have this paragraph: "It is now two years and nine months since the railroad was partially opened for business, and a year and a half since it was opened from Boston to Worcester." By this time, therefore, the railroad was doubtless doing all that it was called upon to do.

Danger there was, no doubt, at grade crossings in those days, when the business of the country made it profitable for a half-dozen trains to cross them daily; but that a railroad company should construct their road, which at that time was almost an experiment, with crossings at grade, instead of resorting to the more costly method of underneath or overhead crossings, can scarcely be thought strange.

In 1842 the second track through Newton was constructed.

From 1883 to 1887 the third and fourth tracks were laid, the portion of the Woonsocket division of the New York and New England Railroad between Brookline and Newton Highlands was purchased and double-tracked and the connecting road between Newton Highlands and Riverside built, giving practically a double-track circuit road from Brookline Junction, independent of main line express tracks.

In 1893 the third and fourth tracks were laid on the main line as far as Lake Crossing, 16 miles from Boston.

It was therefore possible, as far as the operation of the railroad was concerned, to run with safety a large number of trains, many of them at high speed. Meantime, it is needless to say, the traffic on the streets had increased in proportion to that on the railroad.

The question of separation of grades began to be considered seriously about January, 1888. At that time the railroad company made a profile of the road from Faneuil to Auburndale, and surveys of the railroad and adjoining streets as far west as Harvard street.

A profile for the elevation of tracks and depression of streets was drawn, and an estimate made for the construction of about 1½ miles of the work in accordance with it.

In accordance with Chapter 99 of the Acts of 1888, the Governor appointed three civil engineers to report to the general court, "on or before the first day of February, 1889, upon the subject of the gradual abolition of the crossings of the highways by railroads at grade, with such suggestions and recommendations as to the best method of accomplishing such abolition as shall seem to them expedient."

These engineers were appointed July 11, 1888, and their report was dated January 31, 1889.

This commission reported upon all the crossings in the State, and, for the crossings in Newton, recommended that the railroad be depressed through Newton and Newtonville and raised through West Newton. Over the portion which they proposed to depress they did not generally call for as much change of railroad as was finally adopted. The greatest amount was 16 feet. With the exception of Commonwealth avenue, the most that they proposed to raise the railroad at a street crossing was 10 feet, which was at Washington street, West Newton. Their estimate of the cost was $1,300,000.

So far as the writer knows, the next work for the advancement of the grade crossing scheme was that done by the railroad company in the first part of 1892. New railroad and street profiles were drawn and presented at a hearing before the Board of Aldermen in January. Estimates were made of the cost of that portion of the work necessary to eliminate the West Newton crossings. Some of these estimates were based upon a plan for moving the railroad somewhat north of its present location, from Greenwood avenue to Rowe street (now Commonwealth avenue). Work on these plans and estimates continued from time to time through the spring.

Meantime an act had been passed by the Legislature relating to the disposal of private ways across the railroad, as well as highways crossing over the railroad by bridges, in connection with grade crossing work.

Next in order came the appointment of the City Commission. By an order of the City Council of the city of Newton, approved November 22, 1892, a commission was appointed, consisting of the City Engineer, Albert F. Noyes, and two other engineers, Charles A. Allen and George S. Rice, who were, in the language of the order, "to examine the several proposed plans for separating the

grade crossings of the Boston and Albany Railroad within the limits of the city of Newton and report thereon." The order specified three different methods to be considered.

The commission made their report May 1, 1893.

As specified by the order, the first method to be considered was the removal of the tracks to some other locality. The commission selected a route which left the main line about 800 feet east of St. James street, and passed to the north of the present location, joining it again at Auburn street, Auburndale. At Newton, Newtonville and West Newton stations it was respectively 850, 1900 and 800 feet north of the present location. The greatest departure, however, was opposite Bellevue street, where it was about 2100 feet. Estimates were made for both depressed and elevated tracks on this line. With the depressed tracks a tunnel about 600 feet long was required. With the elevated tracks grades of 39 and 51 feet per mile were required.

The second method considered was to raise the tracks and depress the streets in their present locations. The commission recommended the raising of the railroad at important street crossings from about 12 feet to about 16½ feet, the streets being lowered from 1 foot to 5½ feet. The railroad was to be carried over the streets by arches of steel or masonry. The profile of the railroad was somewhat irregular, and called for some steep grades.

By the third method the railroad was depressed and the streets elevated in their present location. The railroad was placed as low as possible consistent with good drainage. The depression at the street crossings amounted to from 9 to 16 feet. Sixteen feet clear head-room between top of rail and under side of bridge was reckoned upon. The streets were to be raised from 2.3 feet to 9.6 feet, except at Rowe street, where, as there was to be no depression of tracks, the street was to be raised 18.5 feet. Both schemes for changes on the present line of railroad provided for four highway bridges where there were formerly no crossings, and one highway bridge at Centre Place, where there was formerly a foot subway, and a foot bridge at Greenwood avenue, where there was formerly a private way at grade.

A summary of the City Commission estimate is as follows:

Proposed northern location, with depressed tracks and slopes, $2,455,700. Raised tracks, with slopes, $2,647,000; with walls, $3,741,000. Present location, depressed tracks, with slopes, $2,090,300; with walls, $2,370,600. Raised tracks, with slopes, $1,965,300; with walls, $2,251,500.

In conclusion, they strongly recommended that the tracks should be elevated.

The report was very carefully prepared, and was illustrated by maps and numerous profiles of both railroad and streets. Much that pertained to such matters as the widening of Washington street I have not mentioned, merely touching upon that which most directly affects the railroad work and helps to complete the list of the many efforts to solve the grade crossing question.

There was considerable opposition by the Newton people to the scheme of elevating the tracks, recommended by the City Commission, and this was manifested at a public hearing in June, 1894.

Nothing more of consequence was done until January, 1895. At this time the city government proposed taking all the land between Washington street and the railroad in connection with the widening of Washington street, over the greater part of the distance covered by proposed changes of the railroad, and by so doing provide room for temporary tracks over which trains could be run while the work of depression was going on.

The railroad company approved of this method, and the city and railroad company drafted an act which was passed by the Legislature in March, 1895, which gave the special powers required to carry out the work as suggested.

From this time on the work of completing the final plans was continued by the railroad company's engineers working in conjunction with those of the city.

On June 26, 1895, a public hearing was held at City Hall to consider the general plans proposed by the engineers. They proved to be satisfactory to both parties, except in minor details, and written agreements between the city and the railroad company, concerning methods to be pursued by both, were drawn up and signed.

The plans being fully agreed upon by the railroad company and city, the petition to the Superior Court for the appointment of a commission was submitted in December, 1895.

The commission was appointed January 2, 1896, and consisted of George W. Wiggin, Joseph S. Ludlam and Homer Rogers.

After a hearing and view of the crossings and several adjournments of the hearing, the commission filed their decision and prescribed the manner and limits within which the alterations they decided upon should be made. Their decision was filed February 29, 1896. The decree of the court confirming the decision was dated March 3, 1896.

The decision of the commission as printed covered fifty-six letter-size pages.

After a preamble, which contained references to some general matters relating to their appointment and to the taking of land for temporary tracks, they proceeded to describe in detail the manner in which the alterations were to be made.

The new base line of location of the railroad was first described by starting at a point a certain distance from the sixth mile-post and giving the lengths of tangents and curves on the new line, and the radii of the curves, calling for stone monuments at all points of change and giving the stations of each. The new north side line of location was next described by starting at a certain distance northerly from the point of beginning of the previously described base line, thence running westerly by a line located by reference to the base line, or to establish property lines intersecting the new side line, or both.

The southerly side line was next described in the same manner as the north line.

Next came the description of the different parcels of land taken, which were outside the present location of the railroad. There were twenty parcels in all, each parcel being described much the same as in the case of descriptions contained in deeds.

The grade of the railroad was next established by giving the elevations at points of change, designated by their stations, and the gradients.

The matter of dealing with streets will be described by the paper to be presented to you by the city's engineer, as well as a description of the changes necessary in the water courses and sewers.

The position of culverts of masonry or iron pipes was given.

Retaining walls of masonry laid in cement were to be built, where shown on plan, and ditch walls were called for.

Land was then taken for railroad slopes, twelve different parcels being described.

It was then stated that the railroad company should do all the work within the lines of the railroad location, and that the city of Newton should do all other work ordered.

The commission decided that the commonwealth should pay 25 per cent. of the total cost of the work and the city of Newton 10 per cent., leaving 65 per cent. to be paid by the railroad company.

A plan, in the form of a tracing, was filed as a part of their decision. It was drawn to a scale of 40 feet to an inch, and showed all existing tracks and all structures and property lines adjoining the railroad property or Washington street. A profile of the railroad was shown on the same sheet also, as well as profiles of all

streets affected by the decision of the commission. The lines showing the changes ordered were red or yellow, and of different conventional kinds.

Showing so much on one sheet at this scale made the plan rather large, 3 feet wide and 45 feet long, but it was, on the whole, very convenient and satisfactory. Three cloth blue prints of it were given to the Clerk of Courts and one to the city of Newton. The railroad company also had one for the Boston office use and one for the roadmaster's office on the work.

The new base line was moved north over a large portion of the work.

From near St. James street to Church street the movement north was from 13 to 9 feet. This was to avoid taking land on the south side. From Mt. Ida west the alignment was changed so as to avoid a reverse curve. At Newtonville station the movement of the base line north amounted to 23 feet. This movement was made practicable by the large amount of space between Washington street and the old railroad location, which was to be taken by the city in connection with the Washington street widening. It made it unnecessary to take valuable land on the south side, and also gave the required room for station facilities. From Newtonville west the new base line is about 19 feet north of the old, as far as the Mt. Vernon street ledge. At this place, on that account, it was not necessary to disturb the old rock slope on the south side, and consequently no land was taken. The new base line gradually approached the old from this point to a little east of Chestnut street, where the two lines come together. At Greenwood avenue the two lines were still far enough apart so that the old retaining wall, holding a high bank on the south side, was not disturbed.

The amount of the depression of the railroad required at some of the important street crossings was about as follows: Washington street, Newton, 16.4 feet; Centre street, 16.4 feet; Church street, 12.9 feet; Walnut street, Newtonville, 14 feet; Chestnut street, West Newton, 11.4 feet; Washington street, West Newton, 10.4 feet.

The actual depth of excavation was about $2\frac{1}{2}$ feet greater than these figures, as sub-grade was 3 feet below top of rail.

A minimum slope of 2-10 per cent. was adopted for ditch grades, and 2 feet 6 inches for minimum depth from top of rail to bottom of ditch. The grade of the tracks is level in some cases, so, for this and other reasons, the depth of ditch below the rail is not uniform. The greatest depth of ditch is 3 feet 10 inches below top of rail. Except where there is ledge, the ditches are paved.

As soon as possible after the decree of the court specifications

for ledge work and plans and specifications for masonry were sent out, and bids received.

Only representative plans of abutment and wall masonry were prepared to send out with the specifications.

The contracts for all work were awarded in April, 1896.

The first work which it was necessary for the railroad company to do was that of preparing a roadway for two temporary tracks about 3½ miles long. Work was commenced early in the spring of 1896. This required the construction of 2500 feet of single and 1040 feet of double-track trestle. One of the single-track trestles extended from just east of Washington street, Newton, to Centre Place, and was built on account of the fact that there were valuable buildings here which it was not thought best to disturb. The next trestle was at Brackett's coal yard. Part of this was double track. The third trestle was that at the city hook and ladder house, near Mt. Vernon street, and was built partly to avoid the entire destruction of this building. These three trestles were all pile structures. The fourth and last trestle was at Eddy's coal yard, and was double track on timber bents, the sills resting directly on the earth. No very extensive grading had to be done, but there were some sharp curves and steep grades. A large number of buildings had to be moved or torn down before the grading could be finished.

On June 28, 1896, all regular business was turned onto the two southerly main tracks, and the work of removing the rails and ties of the two northerly tracks to their position on the temporary roadway was commenced.

July 13, 1896, all the regular business of the road was transferred to the temporary tracks, leaving the old roadway practically free for construction purposes.

In the sections, Figs. 1, 2 and 3, the heavy lines represent the original surface, the hatched lines the finished work and the ordinary lines different stages of the work during construction or details of finished work.

The first cross-section, Fig. 1, shows the work near the St. James street bridge.

The stripping on the right-hand or north side was done by the railroad company's laborers. The other stripping was done by contract in connection with the ledge work. The next operation was that of excavating the rock enough to give room for temporary tracks. The next or third stage was that of excavating on the site of the old third and fourth tracks, the two northerly tracks being reserved for construction purposes. The fourth stage completed the excavation under the old four-track roadway. Work on the

fifth and last stage, of course, could not be commenced till traffic was transferred from the temporary tracks to two of the new and permanent tracks below. This was accomplished July 11, 1897, *almost exactly one year from the time the old roadway was abandoned.* The retaining walls and St. James street abutment, on the south side, were built while work on the fourth stage was going on. The north abutment of St. James street, and the retaining walls just west of it, were built last of all, with the exception of ballast walls.

The next section, Fig. 2, shows the work between Washington street and Centre street.

On the right-hand side there were several buildings which were cut off directly on the location line, which was only a few inches from the back line of the foundation. Much careful sheathing and bracing had to be done here, and special methods for supporting and underpinning the buildings were adopted.

The retaining walls here, as in most cases, were rubble, of large, well-shaped stone, with coping stone of nearly a uniform thickness, the minimum thickness of coping on most walls being 16 inches.

Fig. 4 shows a portion of the work on the north side.

Fig. 5 was taken, when all work was completed, looking west from a point under Centre street bridge. The new station on the left has its floor about 6 feet above the platform. The baggage-room is in a separate building, and has a baggage chute of granolithic from its floor level to the platform. Centre Place bridge is the one next the station. Richardson street, Church street and Lewis Terrace can be seen in the distance.

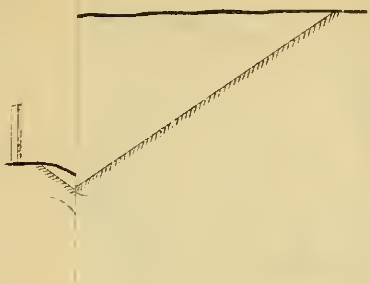
Fig. 6 shows the finished work from Hunt's carpenter shop, on Washington street, West Newton, to the West Newton Station. On the south side retaining walls and abutments are continuous for a distance of 1300 feet, and contain 5300 cubic yards of masonry.

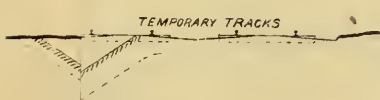
The third cross-section, Fig. 3, shows the operations of the steam shovel where the proximity of street crossings, etc., did not prevent carrying out the order shown. Old track No. 3 was first used as a loading track, and then was moved down successfully into position as loading track for cuts 2, 3, 4 and 5. Old track No. 4 was lowered for use as loading track for the sixth cut.

Fig. 7 is a view of the steam shovel work at the trestle at Brackett's coal yard. It was taken looking east from a point a little east of the location of the work illustrated by the diagram, Fig. 3.

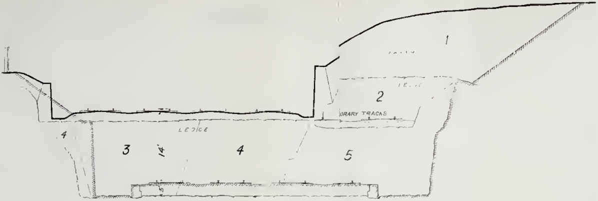
The construction track is the loading track marked 3 in the diagram. At this time it is being used by a shovel just leaving

JOUſE RAILROAD TRACKS.

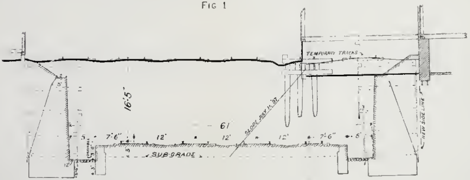




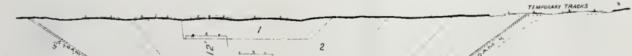
←SOUT NORTH→



ST JAMES STREET LEDGE
FIG 1



WASHINGTON ST. TO CENTRE S
FIG 2



STEAM SHOVEL WORK
NEAR HARVARD ST.
FIG 3

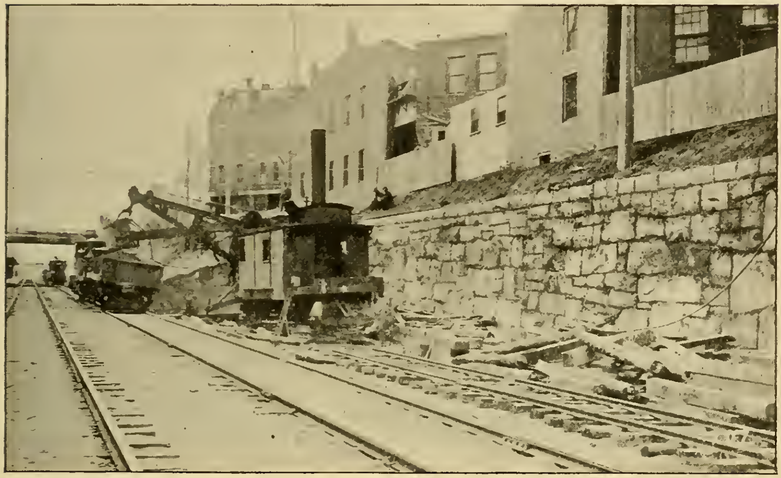


Fig. 4. Steam Shovel East of Centre Street, Oct. 28, 1897.

Fig. 5. Finished Work at Newton Station.

Mt. Ida. The pile of stone on the south side is that which came from the old Bellevue street bridge abutments, and was used for the south abutment of the new Lewis Terrace bridge. The stone lies within the limits of the new street.

Fig. 4 is a view of the steam shovel on the last cut of all the steam shovel work. It is a little east of Centre street. There is another shovel at Centre Place working towards it. The train for this second shovel can be seen about opposite the passenger station. As forty or more regular trains per day passed over the same track that the gravel trains were using, it made steam shovel work rather slow.

One steam shovel began in March, 1896. Other shovels started as there was a chance for them, until four were at work. So much depended on rapid work by them that they were run day and night during September, October and November, 1896. Some night work was also done by one of the shovels in April and May, 1897.

During the busiest part of the season of 1896 fourteen locomotives were in the service daily.

Exclusive of night gangs, the greatest number of men employed at any one time by the railroad company was about 325. The greatest number of men employed upon railroad work at any one time, that is, employes of the railroad company and of contractors working under it, was about 700. The total number of cubic yards of earth excavated was, in round numbers, 706,000. Some of this was used for street filling in Boston under contract with the city, and for filling Commonwealth avenue bridge approaches. The remainder was taken to the dumps at Riverside and Faneuil.

The total amount of rock excavation was about 51,000 cubic yards. About 75,000 yards of ballast was required. Some of this was found on the work, but most of it had to be brought from Wellesley.

There was about 46,000 cubic yards of wall masonry, and the seventeen bridges required about 20,000 cubic yards of abutment masonry.

An arch culvert was required for Hyde Brook, Newton. The old arch stones of Laundry Brook culvert were made to serve for this.

There were several iron pipe culverts, two of them being made up of three lines of 60-inch cast iron pipe. The culverts under the railroad tracks required in all about 700 cubic yards of masonry. So the total for abutments, walls, and culverts was, in round numbers, 66,700 cubic yards.

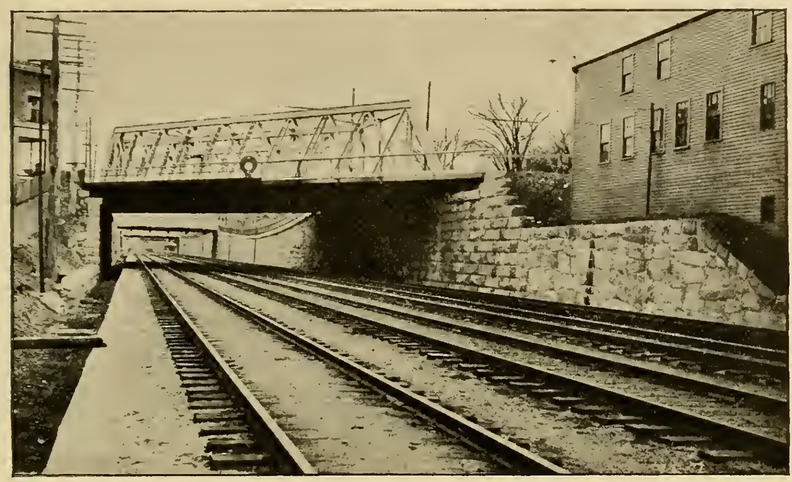


Fig. 6. Finished Work from Washington Street, West Newton, to West Newton Station.

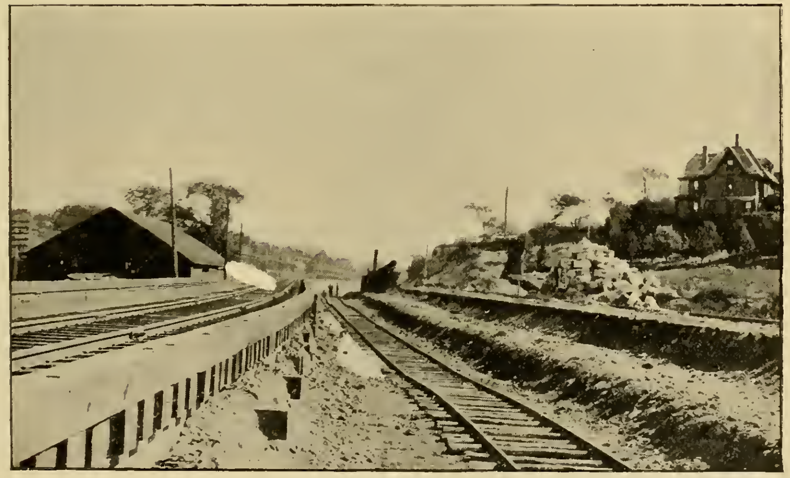


Fig. 7. Steam Shovel Work at Brackett's Trestle.

At Newton a new station of granite, with brownstone trimmings, was built, with the main floor 6 feet above the level of the rail. It is approached by driveways and walks from both Centre street and Centre Place.

At Newtonville the old station was allowed to remain in its original position, steps being built down to the new track level. Walks also connect the platform at the track level with Walnut and Bowers streets.

The old West Newton Station was lowered to within about 5 feet of the new track grade, and the north half of the street in the rear of the station depressed by the city to correspond.

The amount charged to the account of separation of grades by the railroad company for expenditures made by it was, in round numbers, $1,790,000, and by the city $460,000, making a total of $2,250,000 to be apportioned between the railroad company, State and city, in the proportion of 65, 25 and 10, respectively, as decided by the commissioners.

III. Bridges Over the Railroad Tracks.

By W. G. S. Chamberlain.

The separation of grades in the city of Newton made necessary the building of seventeen bridges, all over the tracks of the railroad company, and all within a distance of between three and four miles. Fourteen bridges are plate girder and three are truss spans.

The clear head-room under all the bridges, excepting one, is 16 feet. Under that one it is 18 feet.

The reason for this increased head-room was that the street originally crossed the railroad on a bridge. The grade of the railroad having been lowered, the distance from street grade to that of the railroad was increased so much that it was possible to have a clear head-room of 18 feet and put in a deck bridge. To a person on the street, this bridge will not be particularly noticeable. All that will be seen will be the asphalt surface and the iron fences outside of the sidewalks.

Perhaps the most interesting feature of these bridges is the floor, especially the roadway floor. The foundation for the whole is the same as for any plate girder or truss bridge; that is, floor

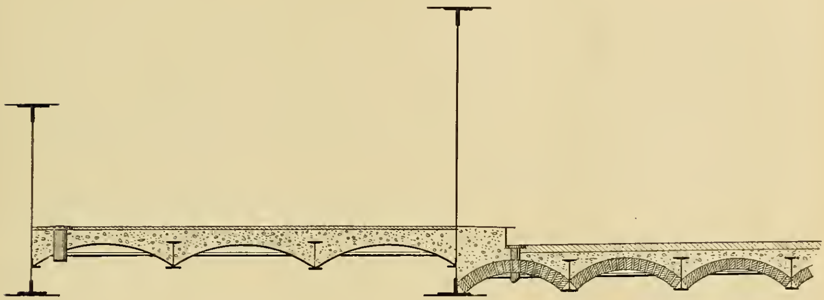


Fig. 1

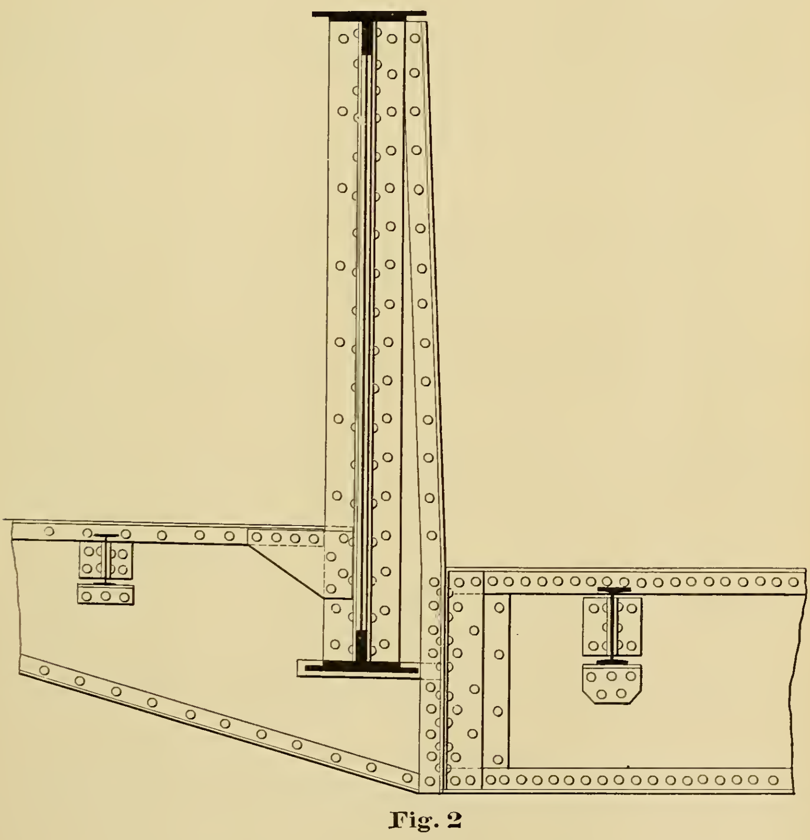


Fig. 2

beams and stringers. The spaces between stringers and girders are filled in with brick arches and concrete, up to within three inches of the finished grade. The remaining space of three inches is filled with one inch of binder and two of asphalt. The surface has a crosswise crown of two or three inches, according to the width of the roadway. Drainage is provided through cast iron scuppers placed each side of the roadway, near the curb channels. The upper end of the scuppers is even with the surface of the roadway, and the lower end is below the lower side of the brick arch. To prevent the smoke from coming up through the scupper, the bottom is curved around, making the outlet on the side. Thus far this arrrangement has seemed to be satisfactory.

The arches have a 4-inch ring, an average span of about 3 feet 4 inches and a rise of 6 inches. The bricks are hard burnt, well shaped and laid in Portland cement mortar. The concrete was composed of one part of cement, two of sand and five of gravel.

The concrete was not placed until the mortar in the arches had set. The centers were not removed until after the concrete had been placed.

In the sidewalks curved plates were used in place of brick arches. Concrete was put in to within one inch of the surface, then the finish was asphalt.

On all bridges where there was no girder outside of the sidewalk the surface was inclined, so that the outer edge of the sidewalk was one inch and a half lower than the inside.

Where there was a girder on the outside, drainage had to be provided through scuppers placed near the outer girder.

When an engine passes under a bridge the exhaust throws clouds of smoke up against the under side of the floor, where it spreads itself out, covering nearly all the under side of the bridge. Near the sides of the bridge the smoke quickly floats out, but back further, in and around the central portion, the smoke will whirl and eddy around, and is much longer in disappearing. The moisture has an opportunity to gather on the surfaces and, holding more or less acid, affects the metal. This was one consideration in favor of the use of brick arches, instead of curved plates, under the roadway. Another was maintenance. Under the conditions already mentioned, it would be necessary, in order to protect the plates, to paint them at frequent intervals. This would be a long and expensive job, as the head-room would not allow the men to work while trains were passing. A third consideration in favor of the brick arch is the strength it gives to the floor between the stringers, thus allowing them to be spaced further apart.

With so little depth to the concrete, it would not seem as if much could be depended upon that for strength.

Fig. 1 shows a section of the sidewalk and part of the roadway. From the surface of the roadway to the lower side of the girder is only about 18 inches. This distance is too small to make proper connection between floor beam and girder; the floor beam also requiring more depth for shear and stiffness. Fig. 2 shows how this difficulty was overcome. The floor beam bracket, made up of a plate and angles, is connected to the girder for its full depth. It is wide enough to allow the angles on the inside to extend vertically down below the bottom of the girder. To these extended angles the floor beam is connected. This arrangement gives the necessary depth for the floor beam. The floor beam is so located in the bridge that it will be midway between tracks and parallel to them. In a skew bridge this makes everything skew, but it cannot be helped. Where the sidewalk is carried on brackets they are connected to the outside of the girder opposite to the floor beam in the same line with it, and then the web and bottom angles are carried down under the girder and connected to the same angles that the floor beam is. This practically makes one floor beam from out to out of sidewalks.

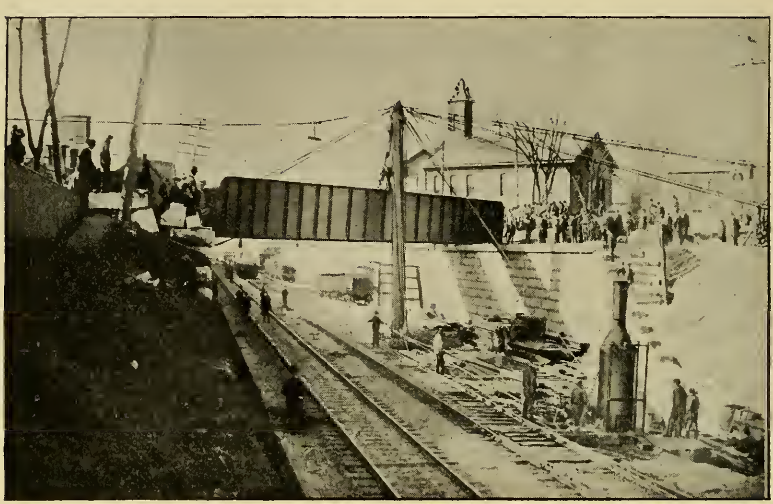
A conspicuous feature of the girder bridges is the great depth of the girders compared with their length. The fact that the distance between the surface of the street and the clear head-room was such that it was necessary to reduce the total thickness of flange plates as much as possible. Hence the depth. The completed bridge does not show this as much as when the girder is seen alone.

The total weight of steel in the bridges is 4,308,238 pounds, giving an average of 253,426 pounds to a bridge. Washington street bridge, West Newton, has the largest amount, there being 583,103 pounds.

The dead load of the roadway, stringers, arches, concrete and asphalt was taken at about 140 pounds per square foot; that of the sidewalk at a little more than 100 pounds per square foot. The live load for sidewalks was taken at 80 pounds per square foot. The roadway floor was calculated for a 20-ton road roller anywhere upon it.

The material used in the construction of the bridges is open-hearth steel, of either the acid or basic process. It was required that the acid process steel should contain no more than 8-100 per cent. of phosphorus, and the basic no more than 6-100 per cent.

No steel was used which showed less than 54,000 pounds per



Washington Street Bridge, Newton, Raising Middle Girder.

Commonwealth Avenue Bridge, Auburndale.

square inch ultimate tensile strength, or greater than 62,000 pounds per square inch. The elastic limit was placed at not less than one-half the ultimate tensile strength. The elongation required was to be not less than 26 per cent. in a length of 8 inches; the reduction of area at fracture not less than 50 per cent.

As a matter of fact, the material more than filled the requirements. The tensile strength averaged about 60,000 pounds, and the elongation and reduction of area in almost all cases was considerably more than required, while the elastic limit averaged about 36,000 pounds.

The material was all inspected at the mills, and specimens subjected to physical and chemical tests.

All shop work was under constant inspection. This part of the work was performed in a very satisfactory manner by R. W. Hildreth & Co., of New York.

Reports were furnished each week, giving a detailed statement of the results of all tests and inspections at mills and shop.

From these reports it was known how the work was progressing, and about what time the bridge would be ready for shipment.

The bridges were built and erected by the Pencoyd Iron Works, of Philadelphia.

All girder work was shipped complete, no field riveting being required.

While the bridges are not ornamental, they yet have a firm and substantial appearance, and are ample for all that may be required of them.

All the plate girders were raised into position by means of a hoisting engine and gin pole. The foot of the pole rested on rollers, so that it could be shifted without trouble. The guys ran through blocks, with the lead lines belayed to the post, so that the pole could be plumbed or canted without sending men away from the work.

The view showing the raising of the middle girder of Washington street bridge gives an excellent idea of the general arrangements and how the work was done. The girder being raised weighed 31 tons, and just about equaled the hoisting power of the engine. The tackle for hoisting this girder included eight three-sheave blocks, with two lead lines to the engine.

POWER CONSUMPTION ON ELECTRIC RAILROADS.

By S. T. Dodd, Member of the Civil Engineers' Club of Cleveland.

[Read before the Club, January 25, 1898.*]

About ten years ago I saw for the first time an electric street car propelled by the power of *forty horses*. To my mind, acquainted only with ordinary two-horse traction, a double 20 horse-power equipment seemed out of all proportion to the speed and size of the car.

Our ideas on such subjects have changed since those days, and to-day no one would thinkof using less than a double 25 horse-power equipment for street railway work; while double and quadruple 25, 50 and even 75 horse-power equipments are so familiar that they pass through our streets without comment.

I suppose no one would expect to operate a twenty-ton car at a speed of thirty miles per hour with the current it takes to run an arc lamp, yet such a mistake would be no more glaring than some that have been made in the development of electric traction. What I now propose is to make an analysis of the losses occurring in electric railway operation and to show that the power of our equipments is no greater than might be expected from the ordinary laws of mechanics, from the weights we are propelling and the speeds, acceleration and grades which we encounter.

The power necessary for propelling a car or train is equal to the product of two quantities—(1st) the speed, which is a definite, measurable and easily recognized quantity; and (2d) the force, the effort exerted by the motive mechanism, or its equivalent, the train resistance. This latter, being more obscure and less easily measured, deserves a careful study.

In analyzing train resistance, four principal divisions must be noted:

(1) Grade resistance, or the effort necessary to lift a train up a certain slope. In electric railroad work this becomes a more important factor than in steam railroad work, on account of the steeper grades encountered.

(2) Curve resistance, or the effort necessary to propel the cars around curves upon the track. This enters as so small a factor that I shall note it here only for the purpose of completeness, and shall not refer to it again.

(3) Acceleration resistance, or the effort necessary to impart to

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a car of given weight a certain velocity in a certain time. On account of the character of the traffic, this becomes a more important factor in electric railroad work than it is in steam railroad work.

(4) Frictional resistance, or the effort necessary to propel a train at a constant velocity over a level track. This division, being the most obscure, shall receive our attention first.

FRICTIONAL RESISTANCE.

The nature of the resistance encountered by moving trains has been discussed by steam railroad engineers for many years. In electric railroad work we have an advantage over steam railroad engineers in the measurement of this quantity. In steam railroad work readings from a dynamometer interposed between the engine and train give only the resistance of the train itself, leaving out of account the resistances experienced by the engine, which in many cases amount to a very considerable proportion of the whole. While the reading of steam engine indicators is a sufficiently laborious and delicate operation on stationary engines, it is much more so when the position of the observer is on the outside of a locomotive running at 25 to 60 miles an hour; and, even with this indicator reading, unless the efficiency of the engine is very accurately known, as it seldom is, we are unable to separate the train resistance from the internal losses in the engine. On the other hand, the determination of train resistance in electric railway work is a very simple matter.

Fig. 1 represents the curves of torque and speed of a street railway motor. These curves can generally be obtained from the manufacturer of the motor, or, if necessary, their independent determination is a very simple matter. The vertical ordinate of any point on either curve represents the current flowing into the motor, while the horizontal distance from the left-hand side of the sheet shows upon one curve the speed in miles per hour at a fixed voltage, and upon the other curve the horizontal effort in pounds which the motor will exert at the tread of the driving wheels when it is taking this amount of current. In order to determine the effort exerted by a car equipment it is necessary only to place an ammeter in circuit with the motors, and the reading of this, by comparison with the curves of the particular motor, gives us immediately the horizontal effort exerted by the motor at that instant, and approximately the speed. For example, supposing the motor in question to be geared with 24 teeth in the pinion and 58 teeth in the axle gear; the two curves marked "Gearing 58-24" in Fig. 1 show that when 30 amperes are flowing into the motor it will exert

a horizontal force, at the rim of 33-inch driving wheels, of 120 pounds, and the car will be moving at 42 miles per hour with 500 volts at the motor terminals. If the ammeter reading is 125 amperes, the same curves show that the effort exerted is 1320 pounds and the speed is $18\frac{3}{4}$ miles per hour. I say "approximately the speed" because the speed is dependent upon and almost proportional to the voltage at the motor terminals, and, as this fluctuates in electric railway work anywhere from 10 to 20 per cent., the speed cannot be determined without a simultaneous determination of the voltage. The torque exerted by the motors, however, is independent of the voltage; a certain current flowing through the coils of the motor will develop a definite pull at the armature shaft. I am aware that this statement contradicts a popular impression that a series-wound motor requires more current to drive a car at a low than at a high voltage, but it can be shown that the statement is absolutely true and that the popular impression is the result of mistaken, or rather misinterpreted, observations.

To return, however, to the question with which we started: How many pounds of pull does it take to move a train of a certain weight at a certain velocity? The formulæ which steam railroad engineers have developed have been in some cases based on hundreds of experiments, but, on account of the widely differing nature of track and train construction, the formulæ differ widely from each other, both in their form and in their final results; and, without intending to criticise the older branch of railroad engineering, I wish to collect here some of the best known of these formulæ and compare them with readings which we have obtained in electric railroad work.

(1) One of the oldest formulæ with which I am familiar was proposed by Mr. D. K. Clark, and is of the form $F = \left(8 + \frac{V^2}{178}\right) W$. V being the speed of train in miles per hour and W the weight of train in tons of 2000 pounds.

(2) Another formula, proposed by Professor Rankine, is of the form $F = \left\{ (5.35 + .268 (V-10) \right\} (T + 2 E)$. T being the weight of the train behind the engine and E the weight of the engine and tender. Professor Rankine's formula is that of a straight line, the resistance being proportional to the velocity above 10 miles per hour and a constant quantity below that. He also recognizes the importance of the head resistance, the "pace-making" effort of the engine.

(3) A formula proposed by Mr. W. H. Searles, and based on his experiments, and which, Mr. Wellington says, has a "wonderful

range of application to all speeds, conditions and classes of trains," is of the form $F = 4.82\, W + .00535\, V^2\, W + .0004783\, V^2\, E^2$.

(4) The most complete and accurate experiments with which I am familiar were made by Mr. A. M. Wellington.

The method used by Mr. Wellington, the gravity method, is free from the disadvantages I have quoted, and is as nearly theoretically perfect as we can expect in work of this nature. The method is based on the well-known principle that a body moving down a frictionless inclined plane will have acquired, at any point of the incline, the same velocity as if it had fallen freely through a perpendicular distance equal to the vertical projection of the inclined path traversed.

Given a train moving at the top of a grade with a measured velocity, if steam is shut off and the train allowed to slide down the grade, with gravity as its only accelerating force, and if measurements of the velocity are made at various points on the grade, the difference between these velocities and the theoretical velocity due to the difference of levels will give us a measure of the retarding forces experienced by the train. Mr. Wellington went perhaps further than any one else had gone. He divides the frictional resistance experienced by a moving train into:

(*a*) Rolling friction, or the friction of the journals and that between wheel and rail, a quantity independent of the speed.

(*b*) Head resistance, or the atmospheric resistance experienced by the first car of the train.

(*c*) Side resistance, or the resistance offered by the atmosphere to the several cars of the train.

(*d*) Oscillating resistance, or increased journal and rolling friction, depending on the speed.

The formula he develops takes account of all these, and is of the form $P = 4\, W + .26\, V^2 + .03\, V^2\, G + .005\, V^2\, W$; G in this formula representing the number of cars in the train.

For sake of comparison I have collected in the table below the results of about twenty observations, which I consider the most trustworthy of those I have been able to get. These observations have all been made on interurban cars running on T rails and over a level track at a uniform speed.

In this table the first column gives the number of cars composing the train, the second the total weight of the train, the third the speed in miles per hour and the fourth the traction coefficient or horizontal effort in pounds per ton of train, as calculated from the current consumption. The succeeding columns give the results of the formulæ which I have already quoted, applied to these

particular cases. The formulæ themselves are repeated at the foot of the table.

TRAIN RESISTANCE.

Comparison of Observation and Formulæ.

No. of Cars.	Speed of Train.	Weight in Tons.	Res. per Ton.	Clark.	Rankine.	Searles.	Wellington.	
1	25.9	20	23.5	11.7	18.	14.8	17.7	23.2
1	28.	21	22.	12.4	20.3	16.8	19.5	23.6
1	32.	20	25.	13.8	22.5	19.8	25.	24.4
1	34.	21	25.7	14.4	23.5	22.6	26.8	24.8
1	36.	21	28.3	15.2	24.7	24.8	29.6	25.2
1	43.	20	27.	18.3	28.4	32.4	42.	26.6
1	45 5	20	27.7	19.6	29.6	35.4	46.	27.
1	47.	20	28.	20.3	30.5	37.8	49.	27.4
1	47.5	20	27.3	20.6	30.75	38.5	50.	27.5
1	49.5	20	25.	21.7	35.9	41.4	54.	27.9
2	27.	35	17.7	12.1	15.5	12.7	14.7	18.7
2	39.	35	20.3	16.5	20.5	21.5	25.5	21.1
2	40.	35	25.	17.	21.	22.	27.6	21.3
2	40.25	35	20.25	17.1	21.2	22.3	27.8	21.3
2	42.25	35	22.3	18.	22.	24.1	30.7	21.8
3	25.	50	16.	11.5	13.1	10.5	11.7	16.4
3	34.5	50	20.	14.6	16.7	15.7	18.8	18.3
3	37.6	50	18.5	15.9	17.9	17.7	21.5	18.9
6	31.8	95	18.3	13.7	11.2	12.25	14.	15.7

Clark $\left(8 \times \frac{V^2}{178}\right) \times W.$

Rankine $\{5.35 + .27\,(V-10)\}\,(T + 2\,E).$

Searles $4.82\,W + .005357\,V^2\,W + .0004783\,V^2\,E^2.$
(Head.) (Side.) (Oscillation.)

Wellington $4\,W + .28\,V^2 + .03\,V^2\,C + .005\,V^2\,W.$

Proposed $(18 + .2\,V)\,E + (7 + .2\,V)\,T.$

V=Speed in miles per hour.

C=Number of cars in train.

E=Weight of engine or motor car in tons of 2000 pounds.

T=Weight of trailer cars in tons of 2000 pounds.

W=Weight of whole train E + T.

It will be noticed that the formula of Mr. Clark is too low in every case to correspond to these observations. The common fault of the other three formulæ is that the velocity plays too important a part in them. At speeds in the neighborhood of 50 miles per hour their results are too high, and at 25 miles per hour they are too low. This is particularly the case with the formula of Mr. Searles and Mr. Wellington, where the velocity enters as the square.

I do not propose to base a formula on the results of about twenty experiments; but, as I have said, these observations are the most trustworthy that I have been able to collect, and it may be of interest to try to find a formula which shall combine their results more nearly than those which have already been proposed. By

plotting these results I have decided on the following formula as expressing, as nearly as possible, the results of these observations.

For a single-motor car weighing E tons, pulling trailers weighing T tons, the resistance in pounds due to the motor car is (18 + .2 V) E, and that due to the trailers is (7 + .2 V) T. The results of this formula have been worked out in the last column, and, by comparing them with the observations in column 4, they will be seen to give a very fair agreement.

As far as my own observations go, for ordinary interurban cars running on straight and level T rails, with roadbed of modern construction, the formula

$$P = (18 + .2\ V)\ E + (7 + .2\ V)\ T$$

expresses very fairly the train resistance between 25 and 50 miles an hour, and, while I do not mean to say that these experiments are exhaustive, I hope this statement may be of assistance to other observers in collecting and stating the results of their observations.

ACCELERATION.

The next question which demands our attention is the power expended in acceleration. How many pounds of pull does it take to give a certain weight a certain velocity in a fixed time? What accelerations are usually attained in practice, and what are the attainable and limiting rates of acceleration?

The answer to the first of these questions is mathematical rather than experimental. If a force P acts upon a mass W to produce acceleration, leaving out of account for the present the force necessary to overcome friction, the acceleration, F, will be equal to $32.2\ \frac{P}{W}$; forces and weights being expressed in pounds and acceleration in feet per second per second. In what follows it will be convenient to express acceleration in terms of the gain in one second of velocity measured in miles per hour, which we will write F_m; $F = F_m \frac{5280}{3600}$.

Transforming the equation above we get $P = \frac{F\ W}{32.2}$. Substituting for F, $P = F_m\ W\ \frac{5280}{3600 \times 32.2}$, or $P = F_m \times W$ 21.9 and if $W = 2000$ pounds, we get the force per ton equal to the acceleration multiplied by 91.3, or pounds per ton $= F_m \times 91.3$.

The curves in Fig. 2 show the accelerations which are obtained in actual practice. Curve No. 1 shows a start of an eleven-car train on the Chicago, Burlington and Quincy Railroad, copied from data given by Mr. Wm. Forsyth in an article, "Tests of Locomotives in Express Service," published in the "National Car and Locomotive Builder," April, 1893.

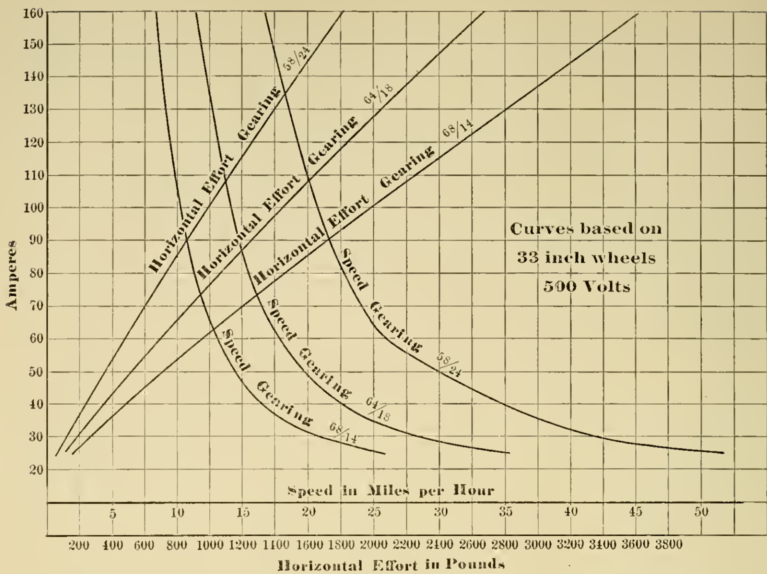

Fig. 1. Railway Motor. Speed and Torque Curves.

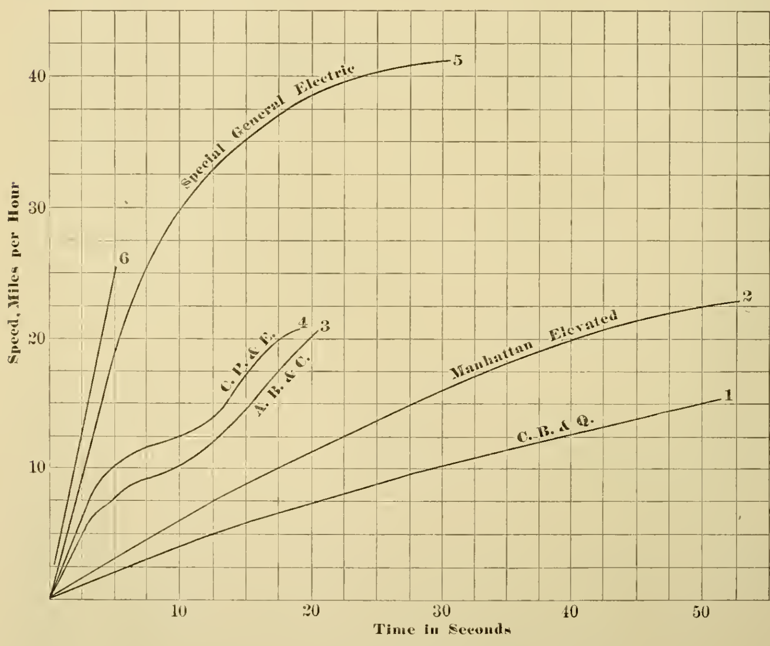

Fig. 2. Acceleration of Trains.

Curve No. 2 shows the start of a Manhattan Elevated train, and is taken from an article by Mr. Geo. L. Fowler in the "Railroad Gazette," March, 1897. Curve No. 3 shows the start of an Akron, Bedford and Cleveland car. Curve No. 4 is a corresponding observation made on the Cleveland, Painesville and Eastern road.

Curve No. 5 is taken from an article by Mr. W. B. Potter, engineer of the railway department of the General Electric Company, and shows the starting curve of a car equipped by that company with a view to experimenting upon very high accelerations.

The following table shows the number of pounds per ton used for acceleration in the various starts shown in these curves, calculated from the acceleration by the formula derived above:

HORIZONTAL EFFORT

FOR VARIOUS ACCELERATIONS AND GRADES.

Roads.	A.	G.	H. E. per Ton.
C., B. and Q., steam	1		36.5
Manhattan Elevated, steam	2		55
A., B. and C, electric	3		183
C., P. and E. do	4		238
Special G. E.	5		348
Limit			470
Woodland Avenue		9%	180
Seneca Street		11%	220
North Hill		13½%	270

The limit of possible acceleration in railroad work is naturally fixed by the slipping of the driving wheels. It can be shown that the start represented in curve No. 5 is very near to this limit. It is generally acknowledged that the adhesion of wheels to rails is, under good conditions, one-fourth of the weight upon them, and under ordinary conditions one-fifth. If we assume, however, one-fourth, and assume moreover that the whole weight of the car rests upon the driving wheels, it will be seen that the limiting accelerating force is about 500 pounds per ton, and, allowing 30 pounds per ton for frictional resistance, we have about 470 pounds as the limiting acceleration. Curve No. 6 shows this limit. That such starts as this are not uncomfortable, if made smoothly, is testified to by the fact that we experience negative accelerations of comparable amounts upon our interurban cars without discomfort. I have myself noted a stop from 25 miles per hour within 90 feet, and from 41 miles per hour I have seen a stop made in eight seconds. As these represent a negative acceleration of 475 pounds per ton, it is evident that the rails were in pretty good condition, and that we had an adhesion of about one-fourth. I might note

that both these were emergency stops, and a little more sudden than ordinary. I am told by motormen upon our suburban roads that, with brakes in good condition, they can always make a stop from 50 miles per hour in five poles, or 450 feet, which represents a negative acceleration of 365 pounds per ton.

From these facts we may conclude that the limit of possible acceleration is fixed only by the adhesion of the wheels to the rail, or by the willingness of railway managers to provide extra power for the sake of increased schedule speeds.

GRADE RESISTANCE.

It is often stated, as an advantage of electric traction, that an electric car is able to mount steeper grades than a steam-driven train. This statement, while true, is often misstated, or rather misunderstood, by those who make it. The advantage does not lie, as many seem to think, in the electric current *per se*, and when steam railroad managers think it advisable to equip an 800-ton train with 8000 horse power in motive power the difference will not be as apparent as it is to-day. The force necessary to lift a train up a grade is the same fraction of the weight of the train that the rise of grade is of the horizontal length.

As an example of some of the grades we meet in practice, we may note that the Cleveland City Railway is operating on Woodland Avenue a grade of 9 per cent., and pulling trailers on that. The Cleveland Electric Railway is operating on Seneca Street hill a grade of about 11 per cent.; the A., B. and C. is operating on North Hill, Akron, a grade of $13\frac{1}{2}$ per cent. To compare these resistances with those ordinarily experienced in acceleration, the latter part of the table shows the number of pounds traction per ton of train necessary to mount such grades.

An inspection of the table shows that the tractive effort necessary on ordinary grades is comparable with that necessary for such acceleration as we ordinarily meet in electric railroad practice.

POWER CONSUMPTION.

Let us apply the data of the foregoing discussion to some problems, in order to determine the power expended in particular cases.

Let us take, as a first illustration, an ordinary city car, which, together with the equipment, will weigh about 12 tons. As may be noted any night after 12 o'clock, going out either Prospect Street or Detroit Street, the maximum speed which such cars attain on a level, after the period of acceleration is past, is about 20 miles

per hour. Applying our formula for train resistance, 18 + .2 V, the frictional resistance of such a car at this speed is about 22 pounds per ton, giving us a horizontal effort of 264 pounds necessary to propel a 12-ton car; and 264 pounds, at 20 miles per hour, is equal to 14 horse power. Assuming that the efficiency of such motors as are ordinarily used at this speed is about 75 per cent., this gives an input at the trolley of 18.8 horse power, or 14 kilowatts, which, at 500 volts, is equivalent to 28 amperes. This represents approximately the amount of current necessary to propel such a car.

As a second illustration let us consider an ordinary double-truck interurban car. The weight of car body and truck, empty, is about 15 tons. The motors ordinarily used for such a car weigh about 3000 pounds. We can estimate the total weight, including a two-motor equipment and a few passengers, at about 20 tons. These cars run upon a level at a speed of about 28 miles per hour. Applying our formula, we get 23.4 pounds per ton, or a total of 472 pounds horizontal effort necessary for propulsion. At 28 miles an hour this is equivalent to 35 horse power. Figuring the efficiency of these larger motors at 32 per cent. gives us 43 horse power, or 32 kilowatts input, which, at 500 volts, gives 64 amperes, or 32 amperes per motor, as the ordinary running current.

Another interesting question is, What should the starting current amount to in cars of this weight? If we take curve 3, Fig. 2, the curve of acceleration for the A., B. and C. car, we see that, at the maximum, as the acceleration begins to fall off (which corresponds to the point where the controller is entirely cut out), we have an acceleration amounting to 1.25 miles per hour per second. This is equivalent to 114.5 pounds per ton, or, for a 20-ton car, about 2300 pounds horizontal effort necessary at this point. As the speed attained with this pull is approximately 18 miles per hour, the motors are delivering about 110 horse power. Figuring the efficiency of the motors at 80 per cent., we get a total input of 138 horse power, or 103 kilowatts, which, at 500 volts, represents 206 amperes as the starting current.

As a final example, let us consider the cars of our latest interurban road, the Lorain and Cleveland Railroad. No tests on this road have as yet been published, but we are promised by the engineers a complete set of tests as soon as the road is in running shape. When such tests are published we shall have some basis for judging of the reliability of the figures above submitted. Such cars will weigh, empty, about 15 tons, or 30,000 pounds. They are equipped with four motors, which must weigh in the neighborhood

of 3000 pounds each. We can safely estimate the weight of car and equipment at 22 tons.

With these cars a speed of 35 to 45 miles an hour is common, and after having gone a mile or so from a stop they attain a speed of 50 miles per hour.

What current do the motors take to propel the car at this speed?

The train resistance on a level is $(18 + .2\ V)\ W$, and since, in the present case, W is 22 tons and V is 50 miles, we have 616 pounds effort necessary for propulsion. Now, 616 pounds at 50 miles per hour is equivalent to 82 horse power, which represents the output of the motors at full speed. For motors of this size we may estimate the efficiency at about 82 per cent. This means 100 horse power input to the motors.

As for voltage, a visit to the power house will show that a voltage of about 600 is carried, and that heavy feeders are used. We can, therefore, estimate that they get 550 volts at the motor terminals. One hundred horse power at 550 volts is 135 amperes. My estimate, based on the data given, is that it takes about 135 amperes to propel these cars after they have attained full speed.

Another interesting question is, How much current does it take to start these cars? If we are allowed to make some assumption, we can estimate somewhat nearly. These cars seem to me to gain speed at the start a little more slowly than do our ordinary suburban cars. Let us suppose that they start under an accelerating force of 150 pounds per ton, or a total effort of 3300 pounds. To this must be added about 23 pounds per ton for frictional resistance, making a total of 3800 pounds.

How much current, flowing through these motors, will produce a horizontal effort of 950 pounds per motor? To determine that it will be necessary to know of what speed the motors are capable at some definite voltage and at this torque. From the car windows we may note that a speed of 35 or 40 miles is very soon attained, but it is not until after we have traveled a mile or so that we reach a speed of 50 miles per hour. We will not be far from correct if we figure that the motor maintains an accelerating force of 150 pounds per ton up to about 25 miles per hour, and that then, as the controller is entirely cut out, the motors continue to speed up and the current falls off, together with the acceleration. An effort of 3800 pounds at 25 miles per hour is equivalent to 254 horse power. Assuming again the efficiency of the motors at 80 per cent., we get an input of 317 horse power, or 236 kilowatts.

At 550 volts this indicates a current of 430 amperes as the probable current during the period of acceleration.

In conclusion, let me repeat the statement I made in the beginning. It often seems that the equipment of a single car with motors of from 100 or 200 horse power is an unnecessary waste of power, but when we consider the weight of car and the loads under which we are operating, the rapidity with which we are compelled to accelerate these weights on account of our frequent stops and the grades which our ordinary highways compel us to climb, we see that ordinary mechanical principles justify the demands of practice for heavy equipments.

DISCUSSION.

MR. W. H. SEARLES.—The experiments upon which Mr. Clark's formula is based were made in the earlier days of railroading and at velocities much lower than those to which we are now accustomed. The constant term is higher than it should be, as proved by later experiments, and this, no doubt, led to the use of too small a coefficient of V^2. The formula is quite satisfactory for a velocity of 20 miles an hour, but is too high at lower speeds, and too low at higher speeds. It is intended for a whole average train, not for a car alone nor an engine alone. Mr. Clark, in his Manual, recommends adding 50 per cent. to meet unfavorable conditions of track or weather.

The later formulas, in three terms, are adapted to a wider range of cases, such as light or heavy trains, high or low speed, etc., but still they are expected to apply only to steam locomotive trains. The conditions of a self-propelled motor-car, with or without a trailer, are so different that we may well look for a new formula to apply to them.

The internal resistances of a locomotive engine absorb a large amount of energy, which, therefore, does not appear as tractive force at the drawbar. Yet this resistance is all counted in and helps to make up the total resistance of the train. The internal friction increases rapidly with the load and with the velocity, and it is this, as well as the atmospheric resistance and the oscillations of the train, that makes the total velocity resistance so high at high speeds.

The resistance offered by modern cars, singly or in train, is pretty well established. The resistance of the engine is not so well defined. It is often assumed at 10 per cent. of the total resistance, and may amount to as much as 16 pounds to 30 pounds per ton of the engine.

The formula proposed in this paper has two distinct terms, one for the motor-car, the other for a trailer. The terms are similar in form, and differ only in the constant. If we suppose the trailer to be loaded until it weighs the same as the motor-car, then T=E, and if we then subtract one term from the other we have (18—7) E=11 E as the internal resistance of the motor equipment, or 11 pounds per ton of the motor-car. This, according to the formula, is constant at all velocities, and it probably is more nearly constant in fact than the internal resistance in the locomotive.

But the constants appear to be too high, as in Clark's formula, and the line of the formula not sufficiently inclined. At 5 miles per hour, at which the resistance of a passenger car is known to be a minimum of not over 4 or 5 pounds per ton, the formula gives (7+1) T=8 T, or 8 pounds per ton; and for the motor it gives 19 pounds per ton. We need experiments on a greater range of velocities, all the way from 5 to 60 miles an hour, before building a formula for motor-cars; but it would seem that if the present formula were written thus:

$$P=(14+0.3V)\ E+(3+0.3V)T$$

it would better meet the general conditions, while agreeing equally well with the few instances cited in the paper. It is hardly possible, however, for a right line formula to represent all the facts. There should be, in my opinion, at least one term involving the square of the velocity.

Mr. L. M. Sheldon.—What effect has the ground return on the cars? In the motors we sometimes find a heavy amperage, but a great deal of it is lost in the rails.

Mr. Dodd.—That is due to high resistance in the ground return, which simply lowers the voltage at the motor terminals.

Mr. Sheldon.—Do you measure the torque by the amperage?

Mr. Dodd.—There is a popular impression that when the voltage is lowered the car takes more current, but it does not. The amount of current required to pull a car over a level track is exactly the same at 300 volts as at 500. There is a certain amount lost in overcoming the resistance of the trolley and of the rail.

Editors reprinting articles from this journal are requested to credit both the JOURNAL and the Society before which such articles were read.

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DEEP BRIDGE FOUNDATIONS, ATCHAFALAYA RIVER.

BY C. H. CHAMBERLIN, MEMBER OF THE LOUISIANA ENGINEERING SOCIETY.

[Read before the Society, August 8, 1898.*]

THE purpose of this paper is to give such facts in regard to the work on the Atchafalaya Bridge as came under the writer's notice, and the excuse for it is that in foundation work experience is a good teacher. A study of facts as obtained from former accomplishments, either of ourselves or others, may help us in present work.

The Atchafalaya Bridge was built in an alluvial section, and the unusual depth of the piers was made necessary by reason of the instability of the soil when acted upon by the river current.

The piers of which this paper treats, being those two nearest the east end of the bridge, were sunk by the pneumatic process, which has so largely superseded other processes on account of the certainty of its application in any class of material.

It is fortunate this method was adopted from the beginning of the work, because the obstructions encountered in sinking would have been more formidable by any other method.

It may not be out of place to remark that the Atchafalaya River, in high water, is a swiftly flowing stream, as compared with other streams in the alluvial portions of Louisiana; and the reason is readily understood. Waters coming down the Red River or down the Mississippi River may divide near the mouth

*Manuscript received September 29, 1898.—Secretary, Ass'n of Eng. Socs.

of the Red; a portion may go down the Mississippi, while the other portion may go down the Atchafalaya. The waters of Red River, therefore, and of the Mississippi above the Red, have two ways to run to the Gulf of Mexico, one the lower Mississippi itself and the other the Atchafalaya; but sea level is reached by the Atchafalaya in about 140 miles from the point of separation, while it is only reached in about 310 miles by the Mississippi. The fall in these distances is the same, being about 53 feet during high water.

The effect of this current on the banks and bottom of the Atchafalaya is shown by the increased and increasing cross-section.

From a stream of very moderate capacity it has, within the memory of men now living, enlarged so that in flood stages it discharges about half a million cubic feet per second.

I have it from reliable authority that the estimated cost of a railway bridge at West Melville, made from the first surveys, was only $75,000, and this, too, at a point about 800 feet above the present bridge and dangerously near the place where the bed of the river is now 120 feet below sea level and the width from bank to bank some 1500 feet.

This enlargement of the river has made work upon the bridge constant and expensive.

Prior to 1894, and since abandoning the transfer boats, the Texas and Pacific Railway Company has maintained its crossing at West Melville by using one 303-foot draw span and two 250-foot fixed spans, all of iron, and trestle approaches at each end. At one time there was a 150-foot Howe truss on the east side, but the sliding bank rendered its foundation unsafe and the trestle was again rebuilt and constantly worked upon. There has also been a Howe truss on the west side, where a 250-foot steel span now is.

The original iron structure rests upon cylinder piers which reach to about minus 84 of the river gauge, two cylinders at each pier, except at the pivot pier, where there are seven. These cylinders are filled with concrete, and those of each pier are braced together at the top. At the east end of the draw, at what we now call Pier II, the attempt was originally made to put in the usual cylinder pier, but the sliding bank broke off the tubes before they were completed and further work of a permanent character was not again attempted till the fall of 1894, when the contract was let to put in a set of cylinder piers at this place and also a set 250 feet farther east, and erect upon them a steel span of modern design.

Mr. A. J. Tullock, proprietor of the bridge works, himself an accomplished engineer, had to assist him Mr. Alfred Noble, of Chicago, as consulting engineer, and Mr. M. A. Waldo, now with


250′
250′
250′
303′
250′
H. W. 37.0
L. W. 1.0
0
50
100
CHAMBERLIN
GREENE
1877
1894
DEPOSIT
CLAY
CLAY
SAND
VI
V
IV
III
PIER II
PIER I
5′
100′
6760
6750

FIG. 1.

the Union Bridge Company, as resident engineer upon the works. To these gentlemen the credit of the design and execution of the work is chiefly due. To the last-named gentleman particularly the writer is indebted for valuable data.

For convenience, all elevations are referred to the river gauge, the zero of which is minus 1.09 feet mean gulf level.

As a preliminary precaution test borings were made close to the pier sites, and showed that from the surface of the ground to minus 30 feet was ordinary river deposit, with quantities of brush and logs; from minus 30 to minus 60 was a blue mud or clay, soft near the top but very firm farther down; from minus 60 to minus 100 was pure sand, fine near the top but getting coarser as it was penetrated, and having in it occasional pebbles.

These borings were verified while the pier work was in progress, and it is worth our while to give at least a passing notice to the material through which they were made. The instability of the river deposit above the stratum of clay has been the cause of all the trouble in maintaining the approaches.

It is needless to expand here upon the natural laws governing a caving bank; suffice to say that all the sliding of the bank at this point has taken place *in* the deposit above the stratum of clay. This is proven by the fact that in sinking Pier II, as soon as the ordinary deposit was passed through and the mud stratum entered, the lower sections of the original piers put down in 1882 were encountered, and had to be broken up and brought out through the air locks. They had moved but little if any after they were first crushed.

Preparatory work consisted in getting the materials and plant on the ground, in providing for the safe passage of trains during construction and guarding against accidents due to sliding banks.

A machinery barge was provided, and was equipped with the necessary boilers, air compressors and pumps and an electric light plant. Old rails were furnished to add weight to the cylinders in sinking. These, when used, were stood on end on the inside of the inner cylinder, just above the air lock; and some also were cross-piled on a frame resting on the top of the cylinder, but in both cases so arranged as not to interfere with the passing of men or material by them.

Fig. 1 shows the profile along the axis of the bridge in 1882, when the original work was done, and in the fall of 1894, just before the new work was started. For comparison the cross-section made in 1877 is plotted. It also shows the location and designation of the piers. The bridge crosses the river in a nearly

due east and west course, the right-hand side of the profile being east.

The present paper has reference to Piers I and II, which were constructed during the winter of 1894 and 1895. The span resting on them was also erected at that time. The span shown at the west end was added three years later. When work was begun

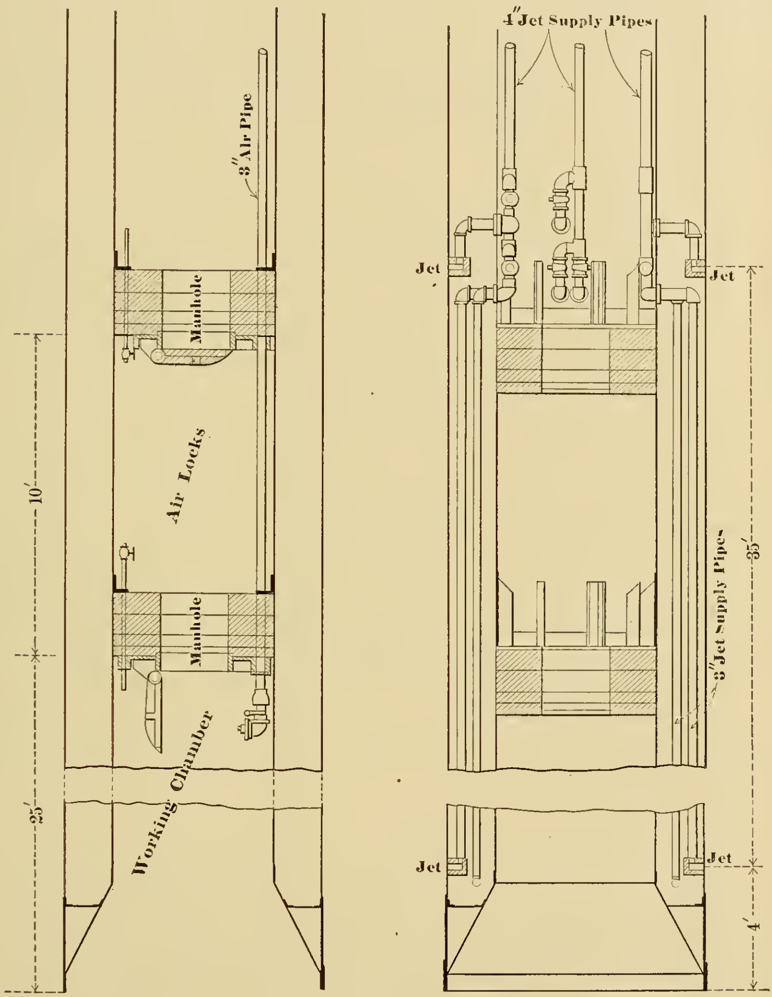


FIG. 2.

there was a pile trestle from the east bank to the draw span, a distance of some 330 feet. Work was first begun on Pier II, and the pier had to be located directly under the east end of the draw.

Foreseeing that any temporary foundation, for supporting the end of the draw and the track, put close to the sinking cylin-

ders, would be disturbed and rendered unsafe by reason of the subsidence of the material around the cylinders during sinking, a plate girder of special design, 50 feet long, was put in, having its center over the pier site. Its ends rested on pile bents. This furnished a temporary rest for the end of the draw, and the trestle was made to connect with its east end, beyond the reach of any dangerous settling of the material.

At Pier I, higher up the bank, this girder was not used, but a span of 28 feet was made of the standard wooden stringers used on the road. These rested on ordinary bents of piling. Whenever they settled the track was blocked up to its proper height to allow the safe passage of trains.

To illustrate the sinking of material: Just after the false work at Pier I was put in it was decided to locate this pier about fifteen inches farther east than first intended, so as to admit of setting the bed plates of another span upon it when the widening of the river makes another span necessary. This movement, slight as it was, caused a very marked difference in the amount of settling at the east end of the 28-foot temporary span over that at the west end.

Pier I was located near the eastern edge of the part of the bank which was liable to cave, as was shown by the warning fissure in the sand running parallel with the river. Trouble with this pier from a caving bank was therefore not anticipated. But for Pier II it was thought best to grade off a part of the stratum of sand which overlies the clay, giving it a slope at which it would stand at low water; because a sliding bank would have caused much trouble in holding the pier in position, if it could have been held at all. Accordingly an excavation was made, with a water-jet, extending from near Pier I to the edge of the bank in the direction of Pier II. It was gratifying later to see that, while both above and below the banks did cave, at the pier no perceptible sliding took place.

Figs. 2 and 3 give an idea of the construction of the piers. Each pier consists of two cylinders, 8 feet in diameter, braced together near the top. Each of these cylinders has an outer and an inner shell, which are held concentric by four webs or stiffeners riveted to each. The inner cylinder is 5 feet in diameter, and was the working shaft. They are in sections of 5 feet, but were added to the sinking pier in sections of 10 feet. Both are made of $\frac{3}{8}$-inch steel plates. The inner shell extends from the bottom of the cylinder to above the ground line, but does not reach the top of the pier. Four feet above the cutting-edge the inner shell begins to

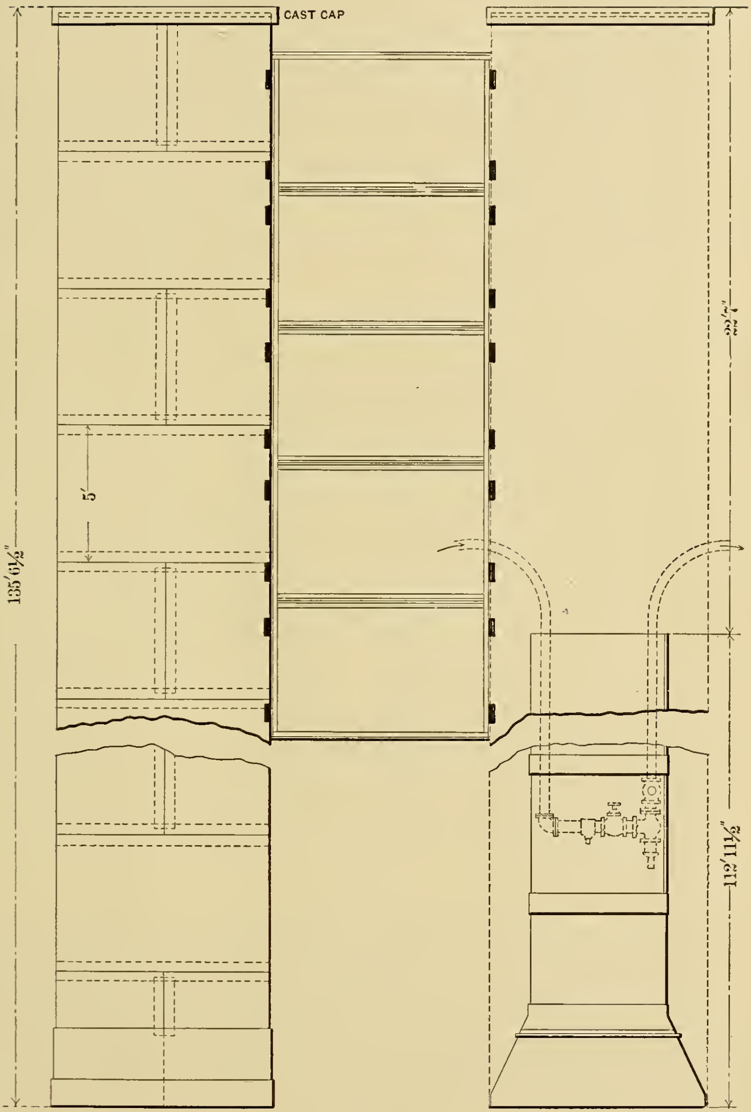


Fig. 3.

increase in diameter going downward, joining the outer shell at the cutting-edge, as shown in Fig. 3.

The space between the outer and inner shells was concreted as soon as the section was added to the cylinder and riveted. This added materially to the weight needed in sinking.

Each 5-foot section was fastened to the sections above and below it by horizontal bands placed on the inside of the outer shell, and on the outside of the inner shell, together with the stiffeners spoken of before. These were all securely riveted together.

A ladder ran up the inside of the inner cylinder. An elevator had been provided to work in the shaft above the locks, but it was not thought expedient to use it.

In Fig. 3, from the cutting-edge upwards for 25 feet, was the working chamber. The air pipe and the pump pipes shown in Fig. 2 entered this chamber. Immediately above the working chamber were the air locks. These were composed of an upper and a lower wooden ring or diaphragm, fitting closely to the inside of the inner shell and securely fastened to it. Each wooden ring was 2 feet thick vertically, and was composed of four thicknesses of oak securely fastened together. The manhole through the center was something over 2 feet in diameter, and was provided with a heavy cast iron door opening downward, having suitable hinges and fastenings. There were four pipes passing vertically through the wooden diaphragm,—viz, the 3-inch air supply pipe, which terminated just under the lock; the 4-inch water supply pipe, for the sand pump; the 4-inch discharge pipe, for the sand pump, and small pipes with suitable stopcocks for equalizing the air pressure. These locks were made with special care, and were overhauled on the ground, to make sure that they were air tight.

The right-hand side of Fig. 2 shows the position of the sand pump.

Fig. 4 shows the pump itself, which is readily understood as acting on the principle of the steam siphon.

Fig. 3 shows an important factor in decreasing the friction between the cylinder and the material surrounding it,—viz, the water jets. These are worth an extended description, as they greatly facilitated the work, not only in sinking the piers but in guiding them.

Four feet above the cutting-edge was a row of holes through the outer shell running horizontally around the cylinder; 35 feet higher was a similar row. These were the jets. All or only a part could be worked at once, as judgment might dictate, except that in this case there was only pump power sufficient to work one full

set at a time. Separate pipes with suitable valves led to each quadrant of a set, so that a part could be operated independently of the other part. The position of the cutting-edge and of the working top of the cylinder was accurately determined every morning, or as often as necessary; and if it was intended to move the cylinder in any particular horizontal direction the jets on that side would be made to run the longer time. It would also often be necessary during a settle to assist the jets and force the top out of position by wedging against a framework built around the cylinder above ground. In this way the cylinder would be temporarily inclined out of its vertical position to be straightened up during some subsequent settle. Of course, as the piers went

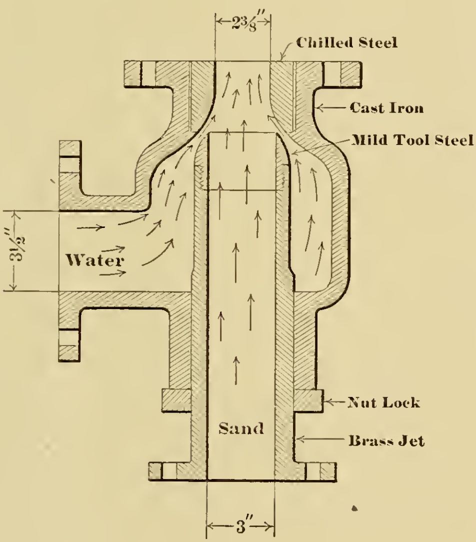


FIG. 4.

deeper into the ground the more difficult they were to control, and it was only to be expected that the cutting-edges would stop at last somewhat out of position, the greater care during the final settle being given to getting the tops in their true places.

The value of the jets in reducing friction was demonstrated on this work in this way: In sinking Pier II they were not needed, and were not used till the cutting-edge was below minus 60, when it was found that the lower jet holes had become plugged with sand and could not be opened; while at Pier I they were used at every settle, whether needed or not, and the difference in the ease with which the two piers sunk was quite marked.

The four progress diagrams herewith give a correct history of the work. The observations from which they were made were taken at eight o'clock each morning.

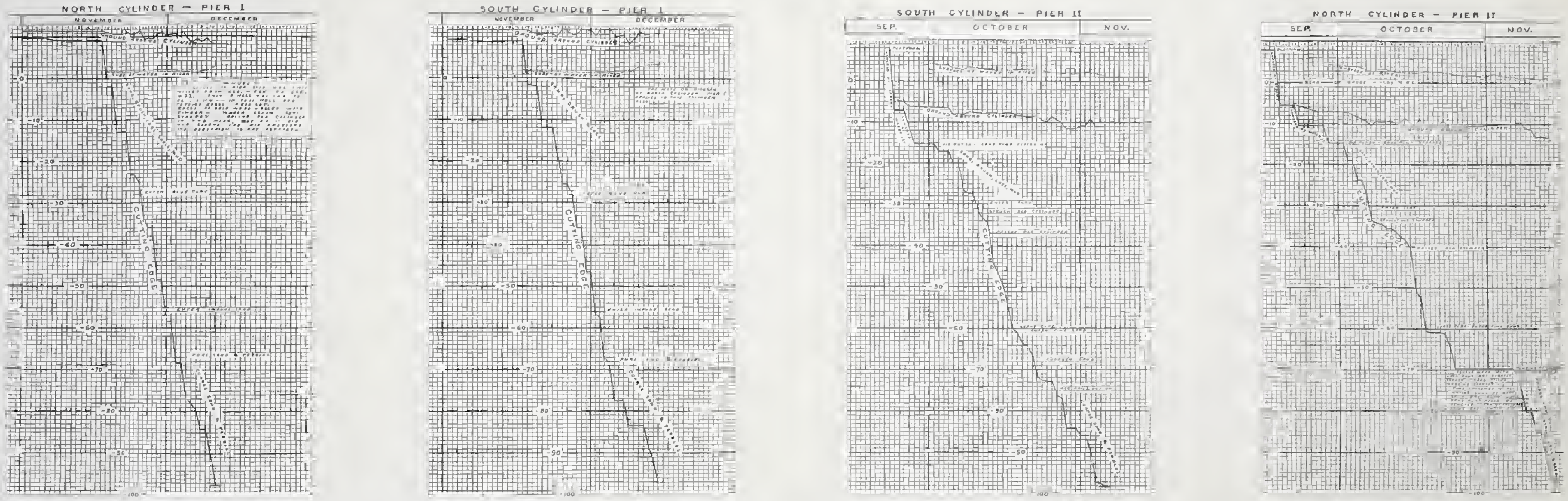
Of one peculiarity it is well to make mention. The air pressure required to keep the water from rising in the working chamber was always equal to or slightly in excess of the weight of the river water displaced, when the cylinders were well on their way down. This goes without saying at Pier II, which was located in the river water; but around Pier I there was always a hole of water varying from 2 to 6 feet in depth, the surface of which was from 9 to 15 feet above the river while the work was progressing, and yet the stage of the river governed the air pressure.

In making a settle the material would ordinarily be pumped out of the working chamber nearly to the cutting-edge. Then the pressure gang, consisting of three men, would come outside. The jets would be started and run for about two minutes; then the air would suddenly be reduced to two-thirds, or sometimes one-half, of its working pressure, when the cylinder would sink. On resuming work the working chamber would be found partly filled with the material through which it was passing. This would be again pumped out and the sinking process would proceed as before. After the cylinder had stood for twenty-four hours or more the first settle would only be a few inches, but subsequent settles, made without any delays due to concreting, or adding sections, or to other causes, would each amount to 2 or 3 feet. When everything was working nicely the operation of the jets alone, without reducing the air, would sink the cylinder several inches. The amount of material pumped out was probably three or four times greater than the actual displacement of the cylinder. This was due to drawing material down from the outside.

When the cylinder reached its final resting-place the pump pipes and the jet pipes above the locks were removed and the operation of sealing begun. Concrete was taken through the air locks in sacks into the working chamber, and was handled and tamped there by the pressure men. In this way all of the space was filled, except just where the lock door swung, and this space was filled with grout after the door was closed. From the lower door to the top of the shaft there was nothing to interfere with rapid concreting, and the work was continuous till finished.

Work now being all above the water line, the air pressure was taken off and the building up of the cylinder to its proper height to receive the cast iron cap was carried to completion. This cap rests on a bed of rich mortar, and is raised above the cylinder about an inch, so that it does not rest upon the shell.

PROGRESS DIAGRAMS.



The physiological effects upon the pressure men, while quite interesting, were not unusual in work of this kind. Of course, the human system is more or less taxed to withstand the effects of compressed air, and members of the pressure gangs would occasionally experience excruciating pains on leaving the working chamber, but there were no fatalities. As the working pressure was increased the hours making up a day's labor were decreased. While the maximum pressure was used, three hours, divided into shifts of one hour each, constituted a day's work.

Any person on entering compressed air experiences first a sensation of great heat; then a painful tingling in the ear is a warning that artificial means must be used to equalize the pressure on the inner and outer sides of the ear drum, else results fatal to that membrane may ensue. Air may sometimes be forced through the ducts leading to the inner side of the ear drum by the act of swallowing. If this does not suffice it may be accomplished by deflating the cheeks as much as possible, having the nose and mouth closed. Failing in this the attempt to enter the working chamber had best be abandoned for the time. The danger attributable to this cause is only present while passing through the locks. The abundant supply of oxygen in compressed air has rather an exhilarating effect upon a person entering a caisson, but labor there is quite exhausting, and there is an opposite depressing and chilling effect upon leaving it.

An idea of the frictional resistance while sinking, though unsatisfactory, may be arrived at.

Take for example the north cylinder of Pier II, on November 13. The depth immersed was 92.85 feet. The air pressure was 40.2 pounds per square inch. This makes the reaction on the cylinder due to air pressure 130 tons. Subtracting the reaction from 295 tons, which was the entire weight of the cylinder with its load of concrete and rails, we get a net weight of 165 tons supported by friction. This, reduced to pounds and divided by 1971, the number of square feet of surface in contact, gives us 187 pounds per square foot as a frictional resistance at the time. But the friction was greater than this, because the cylinder would not move unless the jets were started or the air pressure was reduced. It must also be remembered that air bubbles were constantly arising from under the cutting-edge and from leaks, causing more or less disturbance of the material surrounding the cylinder and reducing the friction.

It would be interesting to know what the friction on these piers is after all the disturbances of the soil have long since ceased.

THE FRASER ELECTRIC ELEVATOR.

By A. E. Brooke Ridley, Member of the Technical Society of the Pacific Coast.

[Read before the Society, June 3, 1898.*]

The employment of elevators in buildings is of comparatively recent origin, and was rendered necessary, in the first place, by the desire of people to spend as little of their energy as possible in non-productive work; and, in the second place, by reason of the aggregation of people in cities. This rapidly increased the price of land, thus inducing an increased height of buildings. Elevators then became necessary as a means of access to the upper stories. As speed was still a secondary consideration, the hydraulic plunger system obtained much favor, consisting of a water cylinder extending vertically into the ground to a depth equal to the height to which the elevator was intended to travel, the elevator cage being placed on the top of the piston rod of this cylinder, which was raised by the admission of water under pressure applied underneath the piston.

The continued increase in the height of buildings rendering this system impracticable, a modification was adopted by placing the cylinder horizontally, the movement of the piston communicating around overhead sheaves with ropes attached to the elevator cage. When the length of the cylinder became extreme a two-, three-, or four-multiple transmission was employed.

In all these types the elevator descends by its own weight, but recently an elevator company has reversed this, causing the cage to run up by its counterweight and descend by the pressure of water, the cylinder being vertical.

To secure the pressure required to lift a given load at a given speed, either city water is used direct or a tank of water is placed on the roof of the building or a pressure tank is provided. On account of the expense and of the insufficiency of pressure, city water is seldom used, but in either of the other cases the water, being used over again, must be pumped by power either to the roof or the pressure tank.

Electricity here found its first employment. The steam pump hitherto employed required a boiler and an engineer, and was very wasteful of steam, while an electric motor could operate a suitable pump, and, when fitted with an automatic arrangement to start and

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stop when necessary, constituted an important economy in operation.

All hydraulic elevators, however the power to operate them may be obtained, have one inherent disadvantage,—viz, that the capacity of the cylinder and the pressure of the water has to be sufficient to raise the elevator at its rated speed with its maximum load; and, however light the load, the same amount of water must still be used, as the cage can rise only as the cylinder is filled with water. Among minor difficulties may be mentioned the amount of space the apparatus takes up, the liability of the water to freeze in the pipes in cold climates and the cost of keeping the cylinder water-tight.

With a view to eliminating the above-named limitations, the direct electric elevator was introduced, it having the immense advantage of consuming power only in proportion to the work performed; and, as is usually the case, the line of invention took the form of operating known apparatus by electricity. Thus, an ordinary mining hoist was connected to an electric motor by belting or gearing, worm-gearing being at the present time generally employed; and this machine is colloquially known as the worm-gear or drum type of electric elevator.

Thus far inventors had plain sailing, but their difficulties increased in arranging for the control of the speed and the reversal of the motors, as, for electrical reasons, it was necessary to energize the field before the armature and then to admit the current very gradually to the armature and yet fast enough to get the elevator in motion rapidly. Next a brake had to be provided, and removed when the power given to the motor was sufficient to lift the load and not before; and, finally, the motor had to be reversed in order to reverse the direction of motion of the elevator. Further, all this had to be done automatically by a simple lever or button in the cage, so as to relieve the elevator attendant as much as possible. These various combinations are operated by means of solenoids and magnets, and these in modern machines operate very reliably. When it is considered how subtle a force is electricity, it is wonderful what good service is rendered by elevators of this character.

This class of machinery has a speed limitation of from 200 to 300 feet per minute, and this is not on account of any want of power. To explain, the elevator has to attain its full speed between floors, and to stop within a very few feet. It is manifestly impossible to use electric current for the purpose by reversing the motor, as the electricity has to be shut off and all connections reversed,

the opposing current admitted to the magnets first, then gradually to the armature. The motor has to stop and start again the opposite way. The only practical method, therefore, is to cut off the current and stop the elevator with a powerful brake.

To illustrate, a 2000-pound elevator must have a brake sufficiently powerful to retain the elevator at rest when loaded to its full capacity, and provided with sufficient surface to bring the elevator to rest promptly at this load. It will, however, be quite apparent that, if the elevator has a load of only a few hundred pounds, it will be brought to rest abruptly, causing discomfort to passengers. Further, the length of distance that the elevator will travel before the brake brings it to a standstill will vary, according to the speed at which it is traveling and the weight that is being controlled. These two factors vary constantly in practical use.

The correct determination of the conditions has to be left to the operator, and in the exercise of his judgment he shuts off the current and applies the brake at a certain period before reaching a landing. Up to a speed of 300 feet per minute, with the elevator working, as it generally does in practice, on a fairly constant load, the operator can stop at landings without much difficulty; but if the elevator is unexpectedly loaded up it is liable to slide a foot or two past the stopping place.

We now come to elevators designed to duplicate high speed hydraulic service, and operating at speeds of from 300 to 600 feet per minute.

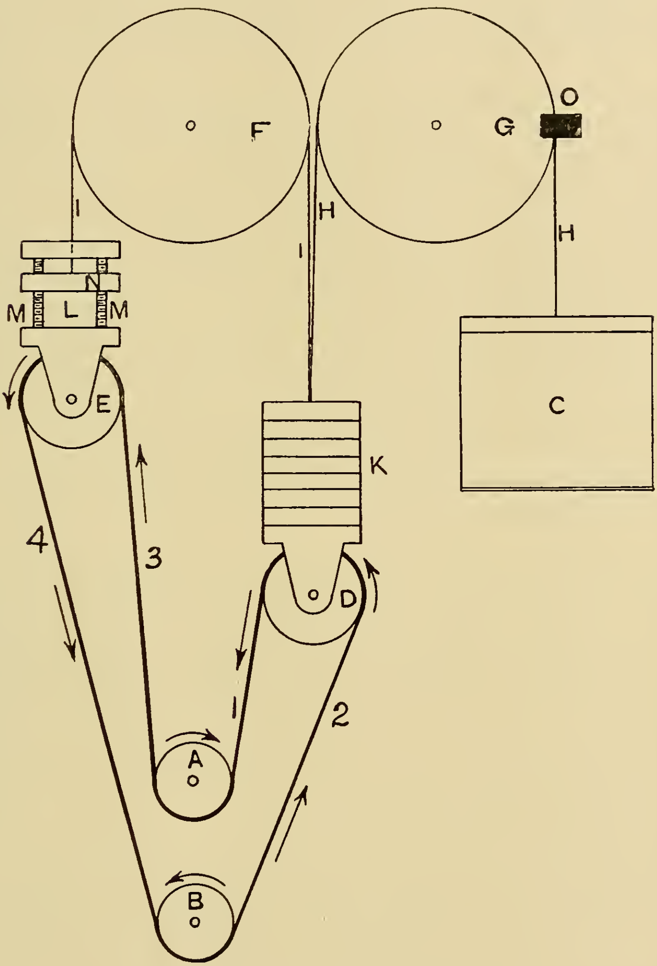
Of these there are three systems, the Sprague-Pratt, the Ward-Leonard and the recently invented Fraser elevator.

The Sprague-Pratt elevator is a counterpart of the hydraulic machine from the car to the water cylinder, but the piston and cylinder are replaced by a screw, which, being rotated, draws up a nut along its length. The rotation of this screw is effected by connecting one end of it directly to the armature of a motor.

The details of this system have been very completely worked out. Ball bearings have been placed between the nut and the screw, the balls running in the thread of the screw. The controlling apparatus is operated by a pilot motor, and this motor controls not only the resistance but also the action of the brake. The button or lever in the cage starts the motor and also operates the main current switch. The car is sufficiently counterweighted to descend by gravity, even when empty.

The motor uses current only while raising the load; in descending the weight of the car revolves the screw and the con-

nected armature. To prevent the elevator from dropping too fast, the field of the motor is excited from the line and the armature terminals are short-circuited through a resistance. This resistance can be varied at the will of the operator, and the speed of the car can thus be controlled. A brake is used to hold the load, but not



Fraser Electric Elevator System.

in stopping the car. While this type of machine can be controlled much better than the ordinary form of worm-gear, for the reason that the machine is always taking current while hoisting and generating current in lowering, the enormous pressure and consequent friction on the thrust bearing and nut, when geared for high speed, greatly increase the cost of operation.

The disadvantage of this machine lies in its complicated controlling devices, requiring skilled attendance, and the large amount of electricity required to bring these elevators rapidly from rest to full speed; for, as the cage descends by gravity, the electricity has to carry up not only the load but a portion of the weight of the car in addition. The direct result of this sudden call for current lessens the pressure in the electric mains, causing what is known as a "wink" in all electric lights operating from the same wire, unless either the elevators are run from independent machinery and wires or the electric wires are very large in size. It is well to mention that the elevator companies disclaim any responsibility for the troubles of the central station man.

With a view to overcoming these difficulties, Mr. Ward Leonard invented a system of control, employing a motor generator which was always running and an elevator of the usual drum type construction, the motor of which was operated by this motor generator, the controller in the car increasing or decreasing the voltage of this generator by means of resistance in the field, thus changing its potential and in consequence the speed of the motor. This arrangement, while it accomplished to a great extent the results desired, requires the use of an additional generator for each elevator, making the initial expense very great and increasing the cost of operation.

Mr. E. M. Fraser, of this city, recently invented and perfected an electric elevator which obviates nearly if not all the disadvantages above mentioned; and I ask your permission to give a somewhat detailed description of this machine, as the prognostications of the elevator have been so completely verified by a practical working of the apparatus. I also think it will prove of considerable interest, as this is the first complete description that has been given before a technical audience.

In the Fraser elevator all gearing of any kind has been eliminated and the motors are never reversed; the brake is used only to hold the car, and for no other purpose. The speed of the elevator is controlled entirely by the strength of the field magnets, and it can be run at any speed it would be desirable to run an elevator.

By this system the best hydraulic service can be duplicated, and the elevator can be operated at any intermediate speed between rest and full speed at the will of the operator.

The apparatus is controlled entirely electrically when running both up and down; and the elevator can be brought to rest

and its direction reversed, allowing only sufficient time to avoid discomfort to passengers.

Its control is operated by making use of the small field current of the magnets, the main armature current being never broken under load. This obviates the most troublesome part of the mechanism usually employed. The operating mechanism consists merely of a field magnet controller and an armature resistance controller.

The system is a modification of the well-known differential principle, as exemplified in the "Weston" differential chain block; with the difference that, instead of having two driving sheaves or pulleys of larger and smaller diameter run at the same speed, two separate pulleys of the same size are run at different speeds. In one system the difference of circumferential speed is obtained by having the pulleys of different diameters, in the other peripheral speed is changed by changing the relative number of revolutions. Two electric motors are used, connected by an endless transmission rope, each motor working independently; and by varying the speed of either armature the car can be made to go up or down.

In the figure, A and B represent two motor pulleys, and C the car; D and E are two idler pulleys, which are free to move up or down in suitable guide strips or posts. The guide pulley D is fastened to the bottom of the counterweight K, and the guide pulley E is fastened to the frame L. This is arranged with two threaded rods, M M, so that the manila ropes, 1, 2, 3 and 4, can be tightened or loosened by screwing the cross-piece N up or down on the threaded rods M M. The tightener L and the counterweight K are connected together by an iron cable I, which passes over a large iron sheave F placed at the top of the well-hole directly over the traveling pulleys. To the top of the counterweight K several iron cables are fastened, and from the counterweight they are run over a large pulley G and fastened to the car C. As the counterweight K moves up or down, the movement is transmitted through the cable H to the car, which is thus moved coincidently with the counterweight.

A very powerful clutch O is so arranged as to hold the sheave G in the event of the current being cut off from the motors A and B from any cause whatever. This clutch is never used to stop the car, except in case of accident.

The action is as follows:

Pulleys A and B revolve in the direction indicated by the arrows, and the manila ropes, 1, 2, 3, 4, move in the direction indicated by the arrow points.

The motors are started, and, so long as they both run at the same speed, the rope simply moves over the various pulleys freely and nothing further takes place.

But if the speed of A is increased and it is thus made to run faster than B, then the part of the rope at 1 moves down faster than the part 2 moves up; and to be able to do that and not slip on the pulleys A and B, D must also move downward. As D is free to move up and down in guides, it does so, and the greater the difference in speed between the two pulleys A and B the faster it moves. When they are brought to the same speed the pulley D and the connected counterweight stop their downward motion.

But suppose now that we speed up the pulley B and make it revolve faster than the pulley A. Then the part of the manila rope 2 will move upward faster than the part 1 moves downward; consequently there must be some slack rope at D. Looking at the rope which passes over the idler E, we find that the rope at 4 moves down faster than the rope at 3 moves upward. The pulley E must move downward to allow this to happen, and, as the pulley E is connected with the pulley D by means of the wire cable I passing over the sheave F, D must move upward and so take up all slack rope, thus keeping the manila transmission ropes, 1, 2, 3, 4, always at the same tension.

The car C, which is connected by the cables with the counterweight K, is made to move fast or slow, or to stop, by simply varying the speed of either motor pulley.

The cage of the elevator is suspended by iron ropes and counterweighted in the usual manner; but for the endless running gear independent manila ropes are employed, these ropes being $\frac{5}{8}$ inch in diameter and seven or more in number, according to the load the elevator is constructed to lift.

The motors are never reversed, consequently no reversing switch or mechanism is needed. When the motors are started they do no work other than to move the transmission ropes over the traveling idlers, consequently the controllers do not have to take care of an excessive starting current; and, as the current is cut off when the car is at rest and the motors running idle, the contacts do not have to break a heavy current at high voltage. The requirements call for a starter or automatic rheostat of very simple construction.

As it is not necessary to start the motors gradually and without jerk, only three stops or contacts are used. The first contact cuts in the armature current through a resistance, and also cuts in the field direct; the second contact cuts out part of the resist-

ance, and the third contact cuts out all the resistance and connects the two armatures directly across the line. The resistance is cut out automatically as the armature increases its speed.

The field coils of each motor are wound in sections, and the ends of each section are connected with a number of buttons in the car controller by a flexible cable. The operator, by moving a lever in the car, cuts out the different sections at will, and so speeds up the armature of either motor, according to the direction in which he moves the lever. To raise the car he moves the lever in such direction as to cut out the sections in the upper motor. To lower the car he simply moves the lever in the opposite direction and cuts out the sections in the field of the lower motor. When he wishes to stop the car he brings his lever to the center. This equalizes the speed of both motors and the car stops.

The automatic starter is so arranged that when a latch is lifted by the operator in the car the motors are started automatically, and when he drops his latch the current is cut off and the motors stop. The operator can stop and start the motors each trip, or he can keep them running as long as he holds up the latch. To prevent stopping the motors while the car is in motion the latch is so arranged that it will drop only when the lever is in the center.

As there is nothing to prevent the car from moving up or down when the motors are stopped, a powerful brake is used to grip the sides of the main overhead sheave, over which pass the cables supporting the car and counterweight. The brake is released by the current and applied by a powerful spring. In the event of the current being cut off, from any cause whatever, the brake is applied. Ordinarily the current is cut off from the brake at the same time the latch is dropped in the controller and the motors stopped. It is impossible to apply the brake while the car is in motion, except by the cessation of the line current; and it is used only as a matter of safety, and not as a means of control.

From the foregoing description of various electric elevators, the essential requirements of a perfect elevator will be understood as follows:

First. Safety.

Second. Ability to fulfill all conditions required at high speed.

Third. Simplicity and reliability of mechanism.

Fourth. Avoidance of discomfort to passengers.

Fifth. Small starting current.

Sixth. Ability to run at any intermediate speed up to full speed.

Apparatus that will fulfill these conditions will duplicate the best hydraulic service in the country at greatly lessened cost and increased satisfaction to all concerned, and will ultimately replace all other types where electricity is available under the well-known law of the survival of the fittest.

DISCUSSION.

Professor Keith.—Though it is hardly pertinent to the subject of electric elevators, I may mention one or two other hydraulic elevators that have been operated, or that could be operated, by accessory electric power in pumping. One of those to which I refer is the telescopic ram hydraulic elevator. More than twenty years ago there was put into the post office building in the city of New York an elevator that obviated the use of a very long plunger. The plunger was made telescopically, so that the depth in the ground which had to be excavated was only one-third or one-quarter of the depth which would have been necessary without this telescopic device. The pistons then ran out as a telescope. Whether that elevator is now in use or not I cannot say.* Then there is the pneumatic hydraulic elevator, which consists of a chamber in which the air is compressed by pumping the water into the chamber and producing the pressure in that way, instead of pumping to the roof of a building or to other elevations.

As to the control used in the Sprague elevator, I think it was in 1892 that the Electrical Engineering Company, with which I was engaged at that time, put the motor at the top of Echo Mountain, in the neighborhood of Los Angeles. I understand that that motor is in use still. It had a device the equivalent of that by which the motor would, upon the descent of the car, be turned into a dynamo, and thus act as a brake.

I would ask Mr. Ridley how he provides against the almost inevitable sparking at the commutator and brushes, due to the change of the strength of the field of the motors in the regulation of Mr. Fraser's elevator. I have been very much interested in the description of the Fraser elevator, and it would seem to me to be a very feasible, practical system. The question that arises in my mind is the possible slippage of the ropes running around the drums or pulleys of the two motors. That may, I presume, be provided against by proper construction of the pulleys.

Mr. McNicoll.—With reference to the slippage of the ropes in the Fraser elevator, mentioned by Professor Keith, they are

*Similar elevators were used for a time, perhaps as long ago, in the freight station of the Pennsylvania Railroad in Philadelphia.—Sec'y, Ass'n Eng. Socs.

run on sheaves turned with V grooves on the rims made with an angle of less than 45°, and, so far, there have not been less than seven ropes run over them in each case. The ropes on elevators that have been running two years show little or no wear, of which the small amount of work they do is the cause. You will note how the balance weight is attached to the car. The car of a large passenger elevator weighs about 2000 pounds, and the balance weight is made of an equal weight with the car, plus 50 per cent. of the load that it has to handle. We find that in the average travel about half of the passengers go up and half come down. So, with this arrangement of overbalance, the load we actually raise by the two motors is equal, in the case I instanced, to only 1000 pounds. That is, if we want to raise an average load of 2000 pounds we have an overbalance in the weight of 1000 pounds, and we use 1000 pounds lifting capacity on the motor to raise the load of 2000 pounds. It is readily seen that the force exerted by the motors is only half of the load it is desired to carry. The weights are carried on all-wire cables, and there are six of those cables used. As they run over large sheaves, there is little or no danger of their breaking. The transmission ropes used are either cotton or manila, and under maximum conditions of load each rope does not carry over 200 pounds, so there is very little strain upon them. The overhead brake in the Fraser elevator is very readily set. It is made on the principle of the Westinghouse air brake; that is, it is always on unless the current holds it off. The elevator can move only when current is applied to the motors, and the moment the motors stop the brake is applied—instantly.

Professor Keith.—Then the current necessary to hold off the brake is the minimum current necessary to run the motors in doing any work?

Mr. McNicoll.—Yes. When the operator raises the lever, in order to move the elevator one way or the other, that movement releases the brake, and the motors can run at their normal speed without moving the car. If there was an extra heavy load, a load heavier than the car, it would have a tendency to move down, or if the car and load were lighter than the overbalance weight it would have a tendency to move up. So the slightest movement of the lever will throw more current into either one motor or the other to hold the load stationary. In other words, the loads can be handled and controlled electrically on the car without the use of a brake. If there was an excessively heavy load on, of course more current would have to be put on the holding motor.

Professor Keith.—Then the question of running several ropes parallel, five or six or seven, and keeping them of uniform length, is one that I should think would have to be considered.

Mr. McNicoll.—They are put on very exact as to length in the first place, and they are all separate ropes, so that if one or two or three, or even four, were to break the balance would still be holding and would be sufficient to hold the load.

Professor Keith.—Yes, but some of them might be slacker than others, even if they were all put on of exactly the same length.

Mr. McNicoll.—That is true. But there is a tightener that takes up all that. Some of the ropes are naturally running with more slack than the others, but from the V shape of the groove they are held in place and by the aid of this tightener the slack is taken up. One very fine feature in the Fraser elevator is that the load can be run at a speed of as high as 700 feet per minute, and it can be run and reversed in the twinkle of an eye; and raised and lowered so that, with the eyes shut, one would hardly notice the direction in which the car was running, so neatly is the movement accomplished with the electrical current, no brake being applied. The change is brought about merely by a change in speed of the two motors.

Professor Keith.—Is the change made in one motor or in both? Do you increase the speed of one and decrease the speed of the other at the same time?

Mr. McNicoll.—At the same instant, yes. That is under the control of the controller in the car.

Mr. Richards.—In what are called electrical elevators the current and apparatus simply transmit energy as do other means, such as steam, air, water, shafts or ropes. There is no such thing as electric power at this time, but the conducting wires form an ideal means of conveying power within buildings where it would be undesirable to erect steam engines. Under that system the steam engines can be centralized in some suitable place.

As to a complete electrical plant within a building, including the original motive power, I must express doubt as to any advantage over hydraulic apparatus, especially when there is special service of the latter for that purpose, as in a number of cities in England and elsewhere, including Australia, where filtered water is laid on at a pressure of 700 to 1000 pounds per inch, thereby reducing the dimensions and cost of the machinery.

No city is better adapted for such a service than San Francisco, but, after several futile attempts, we are without a system here; but we have in its place the electrical transmission, one that

is complete in respect to an efficiency greater than can be attained by a hydraulic system, also with some other characteristics that are desirable. It is perhaps too soon to assume that it is to become general to the exclusion of other methods, but certainly its progress has been phenomenal this far.

Mr. Ridley has run somewhat into error respecting the waste of water by using a constant volume, irrespective of duty. There is one example here, a very notable one, in the Palace Hotel, where there were five hydraulic elevators erected twenty years ago, designed by Mr. G. W. Dickie, our past president, that consume water approximately as the loads are raised. The work was divided, I think, between four separate rams or pistons, with a fifth one to act as a counterweight for the carriages or platforms.

The rams were progressively thrown into action according to the load, and the water was distributed by balanced valves corresponding to the most advanced practice of our day; and I venture the statement that, all things considered, it is one of the most remarkable examples of hydraulic engineering in this country. Some of these elevators have been changed to attain greater speed. How much of the old plant is in use I am not able to say.

In respect to the Fraser system of operating elevators, I will say, as a mechanic (and that is the only phase of the subject with which I pretend to deal), that there are several obvious advantages not only in the mechanism or gearing, but also in its electrical control. Between the rotative motor and the reciprocal movement of the cage the inventor has introduced a gearing that commends itself in many ways. It is not new in mechanics, but it is novel in its application. The fact that the motors revolve continually in one direction is certainly a very important advantage.

From several points of view, I am disposed to criticise the Sprague-Pratt elevator system. I do not see that a screw movement is necessary, and still less why ball bearings are introduced. The primary motion is rotary, and a winding drum is certainly as good a device as the Armstrong pulleys for multiplying motion. There are only a few of these elevators here, and the number is not likely to increase. Ball bearings are suitable when the pressure is light, but under heavy strains balls become the most effectual agent for pulverizing known to the arts. The chilled iron shot used in cutting granite are an illustration. These balls will soon cut a groove in the screw threads and nuts, and the time will soon come when that portion of these machines will be relegated to the scrap pile.

Some time ago I called at the Parrott Building, where eleva-

tors of this kind are in use, but could not gain admittance to examine them. I could, however, see from a guard fence around the machines that the screws were abraded by the balls.

Such devices survive in proportion to their merit. I do not remember that any have been erected except in the Parrott Building and in the Safe Deposit Building. They were made and erected with the utmost care, and I have reasons to believe, as Mr. Ridley has pointed out, that the electrical elements are extremely complicated.

The circumstances that the contractors retained control of the machines for a long time after their erection warrants this statement, and I doubt whether any one can find out much about the operation and present state of the machinery.

I think elevators could have been furnished here for less money, of an equally efficient character and to have given equal satisfaction. I do not know what the future may bring about, but up to this time San Francisco has a foremost place in this branch of engineering work.

There is first the differential hydraulic system of Mr. Dickie, before referred to. A little later on Mr. Milliken introduced his system of single tubes for underground rams. Then Mr. Hinkle's hydro-pneumatic system was extensively applied. Then the over-balance, which divided or reduced the capacity of the motive power nearly one-half, had its origin here. The Moore clutch for belt-driven gearing may also be mentioned. Then came the hydro-steam system of Mr. Hall, the water compensating and traction systems by the same inventor, and then the Fraser system described in Mr. Ridley's paper. Some of these things have spread widely over the world, we may say in modified forms, but originating here.

I may also mention the cable car system, which is only an inclined elevator system in so far as steep grades are concerned.

Mr. Behr.—I would ask Mr. Ridley what pressure per square inch has been allowed on these nuts of the Pratt-Sprague system; what the length of the nut is in regard to the screw, and whether any calculation has been made with regard to the stretching of the screw under pressure. There must be a difference of pressure per square inch between the two ends of the nut. When calculations are based on a uniform pressure it will be found that some of the nuts would heat; that is, speaking of nuts without the ball bearings.

Mr. Barth.—I would ask Mr. McNicoll to explain how it is that to put up an electric elevator, say of the Fraser type, to lift

the same weight as any of the worm-gear machines, costs so much more money than it does to put up a worm-gear machine.

MR. MCNICOLL.—In answer to that question, I will say that one is a mechanical proposition, and there is simply no limit to the work of the screw with small single motors and high gearing. The Fraser proposition, on the other hand, is entirely an electrical and not a mechanical one, and in order to lift heavy loads these motors have to be made of a very large size to do the work properly. There is no gearing employed. Consequently we find that to lift say 2500 pounds with the Fraser electric motors we have to have two motors, which, when stood one on top of the other, stand as high as I stand. That is the reason for the high cost. With the smaller motors we lift lighter loads. We use the power direct from the two pulleys on the motor shafts.

PROFESSOR KEITH.—As both motors move in the same direction, when one motor is increased in speed and the other one is decreased, is there not a tendency from the increase of speed of one to increase the speed of the other as well? What provision is made so that the other may actually decrease in speed? I suppose that that is effected by the change in the strength of the field, as before said. Now, does that change in the strength of the field have to be made greater than would otherwise be the case to decrease it to a given percentage in its speed?

MR. FRASER.—The motors are plain shunt-wound motors, and the shunt-wound motor cannot be run faster than it wishes to go; that is, the moment it is run faster than it wishes to go it turns into a dynamo and generates current. When Mr. McNicoll said we had to have large motors, as is the case, in order to act direct, that does not mean that we use more current than would be used with the other patterns. The large motor takes a large amount of current, but it does not take it all from the power house. The power is transmitted through the rope from one motor to the other. One motor acts as a dynamo, and all the current we really use is the difference between what one motor uses and what the other generates. As we have found in practice, one motor will generate from 50 to 75 per cent. of the total power required. That is the reason why the current is large, that one motor runs as a motor and the other is driven like a generator.

In regard to sparking, we use a very powerful field on the motors, and when they are run at their maximum speed they are running with an average strength of field; and when they are running very slowly the field is saturated, so it does not spark under any condition. With this system we do not start the motors

under load. They are started perfectly free. Consequently the sparking on starting is reduced to almost nothing.

The controlling apparatus that transmits this current to the motor is very simple. The armatures are always revolving when the current is cut off, and consequently there is no arcing on the controller when the current breaks. A switch that is carrying electrical current of heavy amperage and high electro-motive force gives an arc when the switch is opened, and the more current there is the hotter the arc. Any elevator whose motor is started under load suffers from this disadvantage. Suppose the elevator is started upward and that it goes a foot above the floor. It takes an enormous amount of current to start the elevator with the load, and it has moved only a foot. Then the current is broken, and the process has to be repeated every time the elevator is moved. In that way this harmful arcing occurs. We have obviated that difficulty in this system by never stopping the motors with the load on. The motors are always running, the car is always stopped before the current is cut off, the current is reduced to two or three horse power and the voltage between contacts is, at most, about ten volts when the controller breaks the current, whereas in the other style of machinery you must break from 0 to 100 horse power.

Hitherto the great objection to the electric elevator has been the controlling apparatus. It is always causing trouble. If the least thing gets out of order it stops the elevator. We have tried to obviate that in this machine.

Professor Keith.—The motors are placed in parallel, are they?

Mr. Fraser.—Yes.

Professor Keith.—Suppose the normal revolutions, when the elevator is idle, are 1000. What increase of speed would be required for raising the load at the maximum speed? Would it be 2000 or 1800, or what?

Mr. Fraser.—The normal speed of the motor is 225. The speed of one of the motors is reduced to 175 under load, while the other one is speeded up to 600 or 800 revolutions. This gives a car speed, with a 15-inch pulley, of from 600 to 700 feet per minute.

The President.—The whole question of passenger elevators, as has been stated, is of very recent origin. There are several here who can no doubt remember the whole history of passenger elevators. They have been invented and placed in buildings since I have been connected with building operations.

The first passenger elevator of any kind that I ever saw was

in Boston in 1869. It was considered a novelty, and it was a matter of speculation as to whether they would ever become of general use. The first passenger elevator in San Francisco was, I think, erected in the early part of 1872 or the latter past of 1871, when one was put into Bradley & Rulofson's photograph gallery, on Montgomery street, a little cage about 3 feet by 4 feet. The first ones in Boston were steam elevators, and in the early seventies, up to 1875 or 1876, nearly all the development in passenger elevators was in the line of steam-driving machinery, crude generally, and the rope winding on drums. Mr. Richards says that it was nineteen years ago that this system was incorporated in the Palace Hotel. I feel quite certain that in 1876 I saw this hydraulic system at work in the Palace Hotel. It was a very successful apparatus, a very perfect piece of mechanism. From that time on the development of passenger elevators was in the line of hydraulic elevators. I think Mr. Hinkle was one of the first to use the horizontal hydraulic cylinder for running passenger elevators. But, as we all know, that was the method that was taken up and developed, developing the horizontal and vertical cylinders into the multiple rope and traveling cross-head, and increasing the speed thereby to almost any point desired. Other forms of elevator were abandoned generally for the hydraulic apparatus, which, during the past twenty years, has been very fully and perfectly developed. The machine that has been mentioned in the New York post office building was a three-section telescope machine, but it did not run very long. It was put in, I think, in 1875. About that time, or a little before, say 1873 or 1874, developments were made in hydraulic elevators. One was a counterbalance system, in which there was a great bucket to receive water at various stages. It received a volume of water, which was poured into it to counterbalance the weight of the elevator; and it would be received and discharged at every floor level. That was not successful. In the way of screw mechanism, I remember seeing an elevator with two vertical screws, one on each guide-post. It was not successful, as Mr. Richards predicts of the Sprague-Pratt elevator.

When it comes to electrical development and the principles that have been applied to electric elevators during the last seven or eight years or more, we see some of the same stages of development that we have seen in steam elevators. Perhaps the most successful, up to within a short time, of this class of elevators has been an application almost exactly like the original steam drum,

driven by a screw and worm-gear, only driven by an electric motor instead of by steam engines in the building.

With reference to the Sprague elevator, of which Mr. Richards says he does not see what the screw is put in there for, I see clearly what the screw is for, and I do not know how he would accomplish the object in view without it, which object was to carry the cross-head pulley of several ropes that must travel horizontally. It does not occur to me that any better device than the screw could be arranged. But what Mr. Richards says about the ball bearings is certainly true, and can be seen on the elevators running in the Parrott Building. They do crush and grind on the screw. The fact that they require a great deal of attention is vouched for by the case of the Safe Deposit Building elevators. In that building boilers and engines and dynamos were put in. Then the power was shut down entirely, and power was taken from the electrical company. Their engineer was discharged, but it was absolutely necessary to have the engineer there to take care of the elevators. So they must have the services of an expert engineer, although they make no power there. They require a great deal of power, too.

The elevator that has been brought before us to-night is a production of the Pacific Coast. As Mr. Richards says, this city has been wonderful in the line of inventions and improvements, not only in passenger elevators, but in other mechanisms. Mr. Fraser's machine dispenses with some of the greatest objections to electric elevators, such as that of suddenly stopping and rapidly starting a piece of machinery, and breaking the current and reversing it. All that is a shock to any machinery, and especially so to electrical apparatus, to which it is sooner or later fatal. I do not wish to be put in the light of advocating or advertising this Fraser elevator, but I will say this: I examined very closely, and with a great deal of interest, the first one that was put up as a sample machine. A change of speed from the highest speed going up to that going down was made so quickly and so evenly that with one's eyes shut he would not know when he stopped going up and commenced to go down. There is no shock at all. On the strength of my satisfaction with the elevator that was put up for inspection, I departed from my usual rule of not trying a new thing, and put in two elevators, I think the first two commercial elevators of the Fraser type ever put in. I am now about to put in three more in the most important building into which I ever had occasion to put elevators.

While no one else has brought up any objection to it, I will

state here the only objection that appeals at all to my mind, or that I am able to discern, and that is the use of manila ropes, or cotton ropes, or of any other inflammable ropes. I would like to see that rectified. I do not see how it can be done, but it is not a pleasant thing to know that the transmission of the power of your elevator is with material such that if there were any accident or carelessness, and if fire should be applied to it, it would be very quickly destroyed. Possibly that objection could be obviated by saturating the ropes with non-combustible solutions. It would not be fatal, perhaps, if the rope should take fire when the elevator was in use, but it would be a very desirable thing if that possibility did not exist.

Now, Mr. Ridley, we should be glad to hear you answer the questions that have been asked.

Mr. Ridley.—In reply to Professor Keith, I will say that there is no more liability to slippage in the ropes of the Fraser elevator than there is in any other rope transmission machine. It follows the same rule. In a grooved pulley of given diameter one rope will pull a certain weight, two ropes will pull twice as much, and ten ropes will pull ten times as much, and should a rope break from any cause the other nine will still hold the load.

This answer applies also to any unequal straining of the rope. As far as I know, if a strain comes upon one rope at a given time the others relieve it when they are stretched equally. Then, in addition to that, any small difference that may exist is taken up by the pulley and weight at the top sheave shown on the diagram.

The question of motors has been gone into very thoroughly by Mr. Percy, and, as he says, that is one of the very best things in favor of the Fraser machine. In the case of the old style motors, where there was not a continuous action, the breaking of the circuit caused the controlling apparatus to arc, and you were obliged to have carbon contacts which are gradually destroyed. Of course, you can put in new carbons whenever required, but you must have a man to do it.

With regard to the high pressure hydraulic, I do not see that the increasing of the pressure advances the cause of hydraulic elevators, except that, as has been said, you use a little less water. The contention that I made was that whatever hydraulic elevator is used you have to use an equal quantity of water, whether your load is light or heavy. It is this point that the direct electric elevator gets over.

With the exception of the Palace Hotel elevators, I know of very few that have been made with a similar construction, on

account of its complication. But it was a wonderful piece of engineering at the time it was made, as I think we all allow.

As regards the details of the pressure between the bolts and the screw on the screw type of elevator, no data has hitherto been obtainable, and I think that the only means of ascertaining will be by personal investigation.

It has been asked why the Sprague-Pratt, the Fraser, and the Ward-Leonard should be any dearer than the other elevators. In reply, I will say that that is not the case. The Sprague-Pratt, the Fraser, and the Ward-Leonard, and any other high grade elevator cost all about the same price, and you can no more compare one of them with the ordinary worm-gear elevator than you can compare a triple expansion engine with a simple Westinghouse. There is no comparison whatever between elevators that are used for high grade service and the other class of elevators. Then again, if you get an elevator of the cheaper class to raise 2000 pounds it will not raise 2000 pounds all the time. It will be of sufficient efficiency to get through the test, but its average efficiency will not be over a few hundred, and it goes along very unsatisfactorily if the duty is severe.

Mr. Percy spoke of the combustible ropes. I think it is quite possible that non-combustible rope may be used, although it has not yet been tried. Mr. McNicoll, dealing with the practical part, will probably know what experiments have been or are being made in that direction. But as regards the danger, there is no danger, as far as I can see, from the use of a combustible rope. Suppose that by any chance the rope should burn. You have a brake that is always on, and your elevator is just the same as any elevator.

The President.—But the brake does not act while the current is on. Suppose the rope burns while this is the case?

Mr. Ridley.—Then you have your safeties, and it would be the same if the overhead sheaves broke.

Supposing some of the manila rope were burning. There would necessarily, if the car was in operation, be an operator in the car, and by placing the controller in the center the current would be shut off and the brake put on. That would entirely do away with the objection.

Mr. McNicoll.—I would like to state that we had a practical illustration of that when the Phelan Building caught fire a few weeks ago, and burnt the fifth floor and gallery of one end of the building. The elevator itself carried up the fire patrol and all the firemen, and ran for fifteen minutes after the fire started, until

the sheave timbers were nearly burned through. Then the chief engineer told him to go down and open his switches and turn the current off, so there would be no danger. The whole top of the elevator was burning for probably five minutes before it was shut down. These ropes and the counterweight and other parts are generally placed off in a compartment on one side, where they are enclosed and protected more or less from the direct fire that would pass up in an elevator shaft. Another point is that the cage stands in any position, and when the ropes are placed and passed over the sheaves there is no connection between it and the motors. The overhead brake holds the car stationary. Again, not only will the safety catch stop the car on coming down, but upon going up also. On all electric elevators, when there is an overbalance, the danger is just as great, and probably a little greater, that the car will run away going up as in going down. In this safety catch the brake works either way equally well. It has been tested dozens of times.

Professor Keith.—I would like to call attention for the moment to an elevator of which there are quite a number in London, and that is an elevator that is continually going up on one side and down on the other. There is a series of platforms, and an engine is running the elevator continuously. You step off from a platform at the risk of limb, etc., but the risk is very small, as you can walk up the stairs about as speedily as the elevators work there from story to story. There are quite a number of them in London. There are very few, if any, fast moving elevators in the whole city. In fact, there are many buildings three, four, or five stories high in which there are no elevators whatever. It would be probably cutting too much into the conservatism of the people of Great Britain to put in an elevator that would run as fast as those in the Mills Building, in this city, for instance, even after they became so advanced as to have a building ten stories high.

The President.—In some of their hotels they have elevators that will carry you upstairs on application at the office, but you cannot have an elevator to bring you down.

Mr. Richards.—I have had occasion recently to go back over the history of hoisting machines, and the first elevator of which there is any record was made in 1841 by John G. Bodmer, a Swiss engineer in the City of Manchester. He made one to carry his men and freight in his works at Manchester. The machine moved at a fair rate of speed, and was a complete success.

TEST METERS FOR BOILER PLANTS.

By Lehman B. Hoit, Member Civil Engineers' Club of Cleveland.

[Read before the Club, August 12, 1898.*]

The requirements which suggested the use of a measuring machine, or, as it is now termed, a water meter, previous to the introduction of water works plants, are rather indefinite. With the installation of steam-actuated pumping machinery for distributing water to private buildings, manufactories, etc., the value of such a machine became apparent. The enormous increase in the consumption of water by those who formerly regulated the amount they required per day only by the facilities they had for obtaining it soon taxed the pumping machinery beyond its capacity. Habits of waste were encouraged and established under the popular impression that the water supplied was as free as air. The permanent expense of construction and distribution and the question of annual cost were lost sight of until the distributing mains became inadequate, and the pressure for fire protection fell below the point of safety. It was soon learned that merely estimating the consumption of water was disastrous, and it became necessary either to establish a water rate for each and every class of consumer or to resort to a rigid system of measurement. The policy of applying water meters, either as restrainers of waste or adjudicators of value, was adopted by many of the water works corporations, when it was agreed that the proper way to distribute water was to measure it.

It will be admitted by all who have given the matter any considerable attention that a good and reliable water meter must fulfill a great number of exacting conditions, and that the varying services to which meters are applied include a number of requirements.

First of all, a water meter must be accurate under all circumstances,—that is, it should register, with a reasonable degree of accuracy, the amount of water delivered at the various rates of flow, from the maximum capacity of the service pipe to a rate so small as to discourage attempts on the part of the consumer to obtain water without paying for it.

Any variation in the head or pressure should not affect its accuracy. Every gallon of water passed by the meter must produce a corresponding and registered motion in the meter. If on this

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point it is not well-nigh infallible, it is useless to talk of other advantages.

The degree of accuracy should be reasonably permanent; that is, the meter should not be subject to serious deterioration by wear, or affected by sediment or other substances contained in the water, to such an extent as to cause any change affecting its accuracy. Sudden opening and closing of meters should not induce any error in registry.

It must not obstruct the flow or cause serious loss of effective head or pressure. In other words, the meter must be nearly frictionless, and yet so well fitted as to run and register almost on drops. It must be constructed with few moving parts, and these so arranged as to render the possibility of derangement very remote. The parts must be constructed of the best material, selected with reference to their resisting the action of all kinds of water met with in everyday practice.

It must be absolutely reliable, doing its work with certainty, and without the necessity of such frequent care and examination as machines in general receive. In practice, it frequently happens that a meter is not looked at for many months. It will be seen, therefore, that a water meter, to be of any value at all, must combine durability, accuracy, reliability and low cost of repairs.

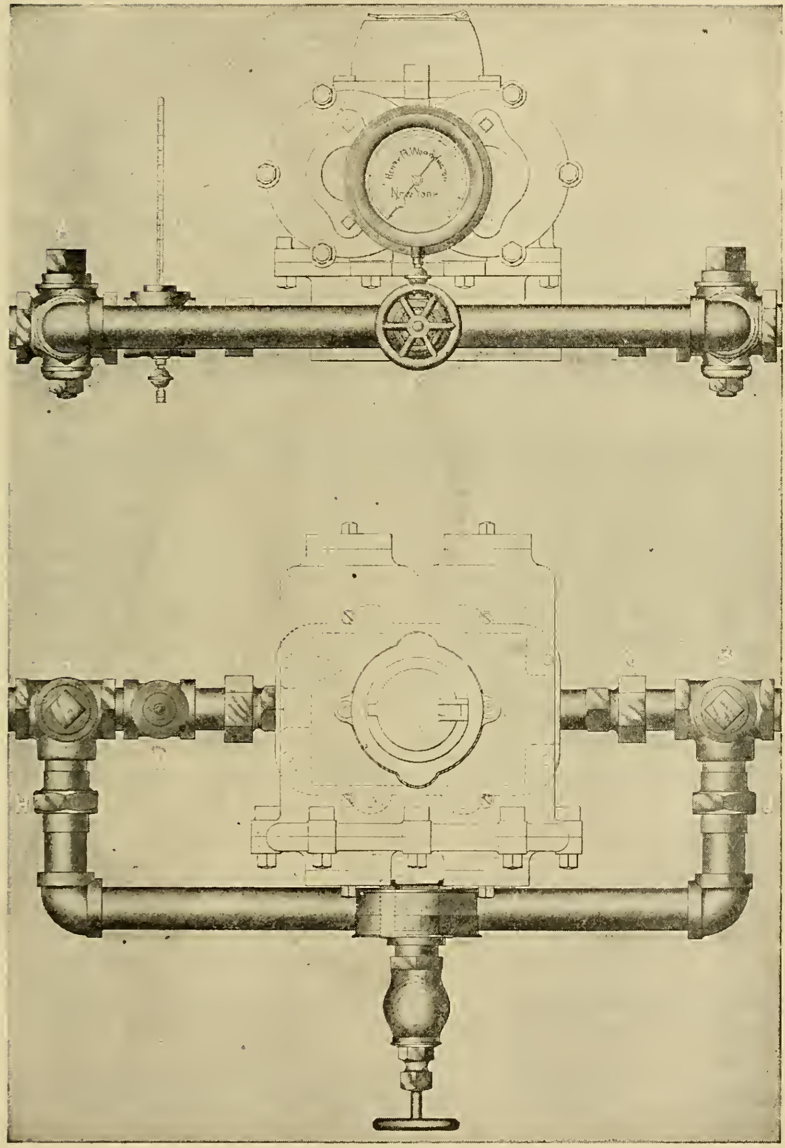
Following closely in the trend of improvements in machinery and the simplification of means for arriving at conclusions, the water meter became a close companion to the steam engine indicator. Its use, in connection with boiler plants, is practically the same as the use of the indicator in connection with steam engines; that is, for determining the actual cost of operating the plant. By the use of the indicator in connection with steam engines, the actual horse-power produced is determined. The test meter in connection with a boiler plant determines the actual cost of producing the steam to furnish the power.

Every engineer who has had control of a boiler plant has felt the necessity of having some simple device by which the amount of water fed to the boiler could be accurately determined. He is able by the use of the indicator to correct any irregularities in his engine or to determine the type of engine that would be the most economical to use. But without a machine for testing the various fuels that could be furnished him he would be unable to determine which of several is the most economical. In addition to this, with the use of a test meter the condition of his plant can be noted at any time without any delay or unnecessary preparation. The old method of testing boilers by weighing the water cannot be applied

9

for general use, owing to the fact that the expense of doing so would in the end amount to considerably more than the saving effected by the observations made. A careful manager naturally endeavors to make comparisons in the performances of his power plant and also of the evaporation of his boilers, from time to time, and, if a practical means of arriving at conclusions is not adopted, he finds himself frequently confused by conflicting results, arising from the supposition that his shop or factory consumes the same quantity of power at all times. Previous to the use of test meters by large manufacturing concerns, the cost of producing the steam necessary was based upon the duty the boilers performed at their test trial. It is found, however, in actual everyday service that the fuel consumption is much greater than the estimate, and that an enormous loss occurs somewhere. Managers were unable to determine the exact cause of this difference without the use of some simple device that would enable them to test their boilers at frequent intervals. A moment's attention to the Worthington meter I have before me may interest you. This meter is in every respect the same as the Worthington meter used by water works corporations, with the exception that the body of it is of composition instead of cast gray iron. The connections on the inlet and outlet sides of the meter are provided with three-way cocks. Extending from one to the other is a by-pass pipe, provided with a globe valve and a steam gauge. In the connection on the outlet side of the meter is placed a fitting for receiving a thermometer. There is no arrangement of feed water piping, pumps, heaters, filters, or other apparatus to which it cannot be applied, and with but a trifling outlay. It can be used without interfering with the operation and usual conditions of the plant for long or short periods, as may be desired, or it can be thrown out of commission entirely.

Owing to the errors introduced by dealing with very hot water under high pressure, the amount registered by the meter may not be exactly the same as that passing through the meter; but the difference between the two is always constant, and, when determined and applied to the counter-reading, the actual amount passing through the meter will be given. It must be borne in mind, however, that the error of the Worthington Test Meter is a very small percentage, and it is only in cases where great accuracy is desired that the counter-reading cannot be taken as final. The conditions being the same as those under which the test is to take place, the correction is readily found by setting the three-way cocks, as above described, so as to pass the water through the



WORTHINGTON TEST METER AND CONNECTIONS.

meter. The reading of the counter, together with the temperature of the water, furnishes (by consulting a table) the weight of the water passing through the meter in any given time. The three-way cock on discharge side of meter is then turned so as to cut off the boiler connections and allow the water to flow by the way of the angle valve placed in the loop around the meter and empty for precisely the same time in a cask or tank placed on a scale; the valve first having been closed until the pressure shown by the gauge is the same as when the water is passing through the meter against the boiler pressure. The relation between the weight of the metered amount and that found by actual measurement gives, in a percentage plus or minus, the correction to be applied to the counter-reading. In this way it is possible to test the meter as frequently as may be desired. Further, by properly setting the three-way cocks, and breaking the couplings, the meter may be removed without interrupting the flow of water to the boiler, or hindering in any way the operation of the plant.

In many of the plants which we have equipped with these meters the connection, as just described, has been left out. In such cases the meter is in constant service from the time the boiler plant is started until it is shut down for repairs. In many cases we have applied the meters in relay, thereby making the registrations of the meter almost positive. This is a much better plan for reasons which are apparent. By operating one of these meters for any given time and noting the readings on the log book in charge of the engineer, the duty performed by the boilers is recognized. The test meter not only determines which kind of coal produces the best result, but also restricts the waste of coal by the firemen. In several plants in which we have placed these meters great economy was effected. The economy was obtained by the careful use of coal, the regularity of attending to the boilers and in keeping the boilers thoroughly cleaned.

We have recently completed a test for one of the oil companies of this city who have a large number of our meters in use. The service required by these meters is rather a difficult one, owing to the fact that the maximum head is not over 8 feet, and the minimum about 8 inches. The maximum quantity is about one-twentieth the capacity of the meter, and the minimum about one-seventy-fifth. We took the oil tank and filled it full of water. This was carefully weighed, and the weight of the water at that time was noted. The water was then removed, and the tank was filled with oil and strained through the meter. It was again weighed and noted, and the error was one-sixth of one per cent.

Any meter which depends upon a rotary motion will show a percentage of error with different pressures. We took for our test one of the best rotary types in the market. We also took a disc meter, and placed them in series, allowing the same quantity of water to pass through the three different meters. The Worthington meter had been tested previously, and was found correct. It had been used under the same conditions as the others. The rotary meters showed very close in actual measurement when the flow of water was nearly up to the point at which it was rated, but when the quantity was lessened so that the discharge was not over one-seventieth the capacity, the difference amounted to 106%. This fact was taken advantage of by many concerns using rotary meters when they found the water would not register when it ran slowly. In St. Paul a peculiar case was noted. Several Chinese laundrymen found that by letting the water run slowly all night long they could fill their tubs without any expense. In the Worthington meter, if you will allow the water to run slowly, it will register just the same, and when it is reversed it will not work. The meter has grown from a plaything to a commercial piece of mechanism.

The Worthington meter has not changed in any of its principal features since it was first constructed. We have found by experimenting that with a certain class of meters we get better results than with other classes. We have been conservative in our ratings; they are the same as they were about forty-five years ago. The use of meters for boiler tests is coming rapidly into use. It is only the question of a few years when there will be no steam plant economy without some type of machine for registering the amount of water passing into the boiler to determine the evaporation.

DISCUSSION.

Mr. E. P. Roberts.—I have been very much interested in Mr. Hoit's remarks, and think he has possibly put the case too mildly as to the value of the meter. He made one statement which I do not think he intended, and that is that you obtain the horse-power of the engine from the indicator cards, and that the principal value of the meter is in connection with the evaporation of the boiler. As a matter of fact, the obtaining any knowledge of the water from indicator cards is very questionable. The only way we can do it is to use the indicator cards to obtain the horse-power and measure the water before it goes into the boiler. The man who is using steam power studies all the items of economy

after the steam reaches the engine, but does not study so carefully up to that point. The water meter is necessary if he is going to obtain the exact cost of his steam, and the difference in the value of the fuel. One fuel at $1.25 may be more expensive than another at $1.50. He can learn this only by getting the evaporation of the boiler. Considering the very small cost of a meter, it seems remarkable that there is not one in almost every steam plant. We have had occasion to advise the use of a meter in a considerable number of plants, and in only one case have we found a man who was willing to spend the amount necessary. The water meter would receive greater favor if it were not for a suspicion as to its accuracy, but I think it is a recognized fact that where the Worthington meter has been used the results have been very satisfactory, even without calibration, and with calibration at time of test it is very convenient. I have just come back from two long boiler tests without the use of the meter, and it is neither pleasant nor easy to get the readings.

Mr. A. H. Porter.—I would like to inquire about the life of the meter, whether it has to have any special care, and whether any tests have been made of old meters to note the effect of wear upon them.

Mr. Hoit.—I can answer that question very easily, for the simple reason that I have in mind now two meters, one 21 years old and the other 19. The way it was discovered that this meter had been used 21 years was that the party who owned it received a bill from the Water Works Department for $2.50 for repairs, which he refused to pay. The early contract did not stipulate that he should keep the meter in repair, and they, in looking up the case, found that the meter was 21 years old. We tested the meter and found it 4 per cent. out. This meter was in Cincinnati, where the water is notoriously muddy.

The other meter is one which is now used in the Turkish baths in Cincinnati. The proprietor was taken ill and obliged to go West. He made readings before he left, and on his return he did so again, and found by the amount of water used that the receipts of his office should have been larger than were reported. Either the water or the money had been allowed to run to waste. This meter was 3 per cent. out after 19 years' service. The meters we have in this city have shown remarkable records, and the cost of repairs is very small.

Mr. C. O. Palmer.—About eight years ago, while I was in the employ of the Standard Oil Company, it was decided to test a certain rotary meter. For this purpose the meter was attached

to the oil supply pipe of the tank-wagon department. The oil flowed from a gauge tank in which it was accurately measured, affording a very good test of a meter, so that I looked for the result with interest. I did not take the readings myself, but those in charge told me that the meter was away off. It was absolutely useless as a check upon the man who had charge of the gauge tank.

The same company had used several piston meters for a number of years to measure the water supplied from its own water works to different departments of the plant. The water was taken from the river and contained more or less mud and sand. On one occasion I was told to test a couple of these meters which had been already connected with a gauge tank for that purpose. The first of these, a Worthington meter, No. 36,071, registered 19.96 per cent. of the amount passing through it as shown by the gauge tank, the flow being at the rate of 7.46 cubic feet per minute.

At another test, the same meter, as I remember, was placed on the outlet pipe, together with a 2-inch Worthington meter, No. 31,451, so that the discharge passed through both. With a flow of 3.3 cubic feet per minute, as determined by the tank measure, the result was as follows:

Tank measure	485.84	cubic feet.
2-inch meter	514.	" "
4-inch meter	90.	" "

This result goes to show that the readings of an old meter are not to be taken without question, and that when a leaky meter is run at a rate much below its normal capacity, as often happens, even a piston meter may record but a small fraction of the water passing through it, especially when it has not been fitted and calibrated for the place in which it is intended to run.

Mr. Hoit.—In testing or calibrating old meters, every condition must be considered, i.e., the pressure under which the meter is operated, the character of the water passing through it, the maximum quantity to be delivered at any one time, and the average quantity to be delivered at all times. In testing the 2-inch and 4-inch meters referred to, probably the same connections were used for both. This would be an incorrect method, and would in itself result in error in one or the other of the meters, even though they were absolutely correct under the conditions for which they were sold.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ROMAN CONSTRUCTION.

BY G. W. PERCY, MEMBER OF THE TECHNICAL SOCIETY OF THE PACIFIC COAST.

[Read before the Society, September 2, 1898.*]

MANY books have been written and innumerable plates have been published describing and illustrating the wonderful architectural and engineering works of the ancient Romans.

The history of Roman art is well known. Their architectual forms are recognized by every intelligent observer, and the minute details of their style and orders have been familiar to architectural students for the last three centuries.

There is hardly a known fragment of Roman architecture in existence that has not been carefully measured, drawn and published to the world during the present century.

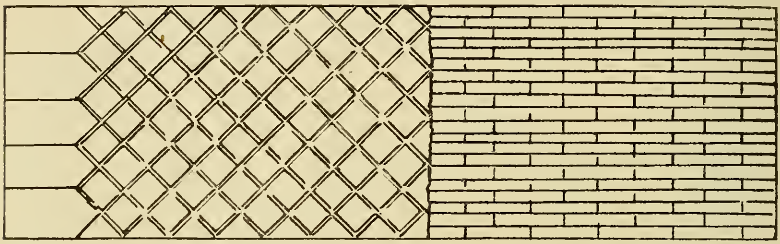
And yet, with all this widely published knowledge of Roman art and architectural forms, there has been very little attention given in modern times to Roman methods of construction, and very few, even among architects and engineers, are aware of the fact that the ancient Romans, especially of the best days of the Roman Empire, devised and perfected a method of construction perfectly adapted to their gigantic works and possible of execution with unskilled labor and with the cheapest and most common materials.

Nearly all writers who have attempted to describe Roman buildings and the materials with which they were built, have classed them as of cut stone, or of brick faced with marble.

*Manuscript received October 4, 1898.—Secretary, Ass'n of Eng. Socs.

Others who have investigated a little beneath the surface have described some Roman walls as a combination of brick and rubble stone work, with occasional bond courses extending entirely through the walls, consisting of large flat tiles.

Vitruvius, the earliest architectural writer whose works have come down to us, declares, in the introduction to his ten books, that he has developed all the principles of the art of architecture. Yet, while he describes very minutely all classes of building material and their proper use, he gives no hint of what the ruins show to be the true Roman construction of walls and arches, which method became general about his time. Whatever Pliny and



ELEVATION.

a b

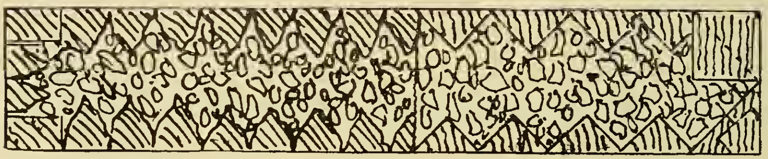


FIG. 1.
PLAN OF WALL.

other ancient writers have recorded of Roman construction they appear to have copied from Vitruvius.

During a visit to Rome in 1882 the writer was much interested in examining the stupendous ruins of buildings, aqueducts, etc., and noticed what to him was a strange discovery,—that the walls and arches of such buildings as the Baths of Diocletian and Caracalla, the Basilica of Constantine and many other ruins were not of bricks, as he had been led to suppose, but of great masses of concrete, faced with bricks. In many places where the brick facing had been stripped off the concrete mass presented a rough face with numerous indentations, as if bricks had been laid diagonally with the corners penetrating the concrete. This was a new revelation to him, but he had neither the means nor time to

investigate further than what was on the surface and exposed to view. The discovery, however, added new zest and desire to read whatever he found about Roman construction. When in 1885 a book was published by J. H. Middleton, an English architect, entitled, "Ancient Rome in 1885," giving the result of extensive investigations, and revealing the fact that all so-called brick walls in Rome of ancient construction were of concrete, faced on both sides with triangular bricks. Middleton declares that there are no walls of ancient Rome built throughout of brick, and that walls only seven inches thick are faced with very small triangular bricks and filled with concrete. See Fig. 1, *a*.

This made clear the cause of the indentations which had so puzzled the writer, and showed a logical intent on the part of the builders.

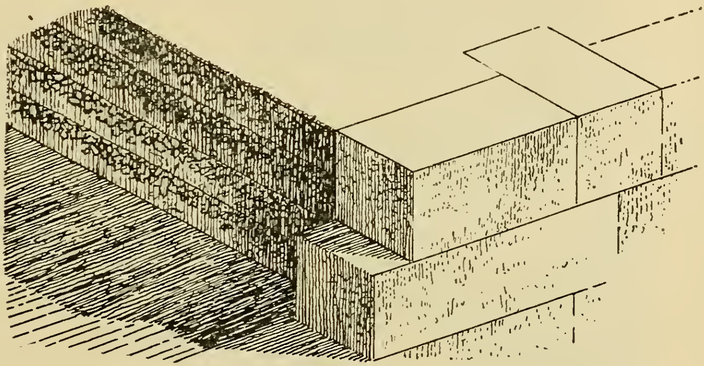


FIG. 2.

In a more recent work, "The Art of Building Among the Romans," written by Auguste Choisy, a French architect, a translation of which by Arthur J. Dillon has been published in the *Brick Builder* during the years 1892-95, makes clear to English readers for the first time the system practiced by the ancient Romans. To this work the writer is indebted for the graphic illustrations of this paper, and to some extent the descriptions.

The etchings by Piranasi show how some of the ruins appeared one hundred and fifty years ago, while the photographs show the appearance of other ruins at the present time.

It will be seen by examining these etchings and photographs* that in many places what appear on the surface to be brick arches over openings and relieving arches through the body of brick walls have fallen out or have been destroyed, and the remaining mass shows that the arches, like the plain facings, were but skin deep.

*Etchings and photographs omitted in publication.

A close examination of the interior surfaces of domes and the soffits of large arches often reveals a framework of thin brick arches forming a skeleton of bricks imbedded in the mass of concrete or rubble work.

Auguste Choisy made a thorough examination of these and other peculiarities and arrived at the following conclusion: That Roman masonry generally consisted of an agglomeration of small stones and mortar, with facings of cut stones or triangular bricks, except for foundations and other works below the level of the ground where the earth, and sometimes timbers, served to confine the mixture. This concrete or fine rubble work is of two kinds—that which was placed in trenches or behind solid stone revetments was of rammed masonry, formed by spreading a layer of mortar

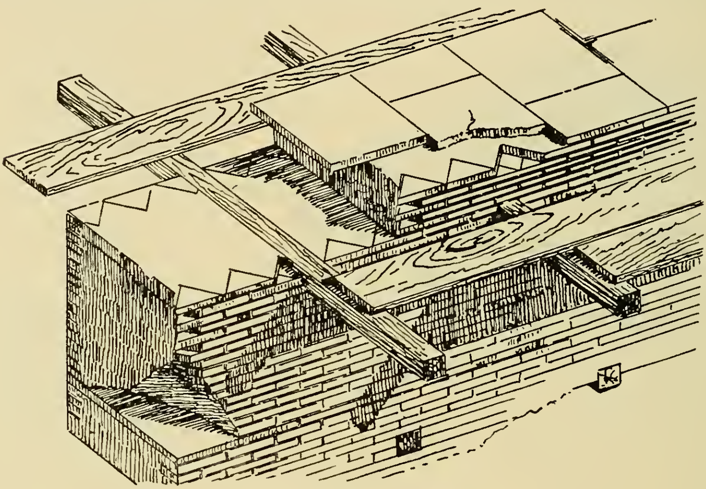


FIG. 3.

four or five inches thick, and then spreading over it a layer of equal or greater thickness of small broken stone and ramming the stone down into the bed of mortar, thus forcing the mortar into all the interstices and bringing some of it to the surface. Then a thin layer of very fine fragments and dust resulting from the facing of the cut stone was spread, which prevented the mortar from adhering to the feet or tools of the workmen, and the whole was again rammed solid, when the operation was repeated with a fresh layer of mortar, rock and dust, thus making a very compact mass in well-defined layers eight or nine inches in thickness. Fig. 2.

This method seems to have been employed in all cases where heavy cut stone facings or earth pressure gave sufficient resistance to the outward thrust caused by the ramming.

The other method of building with conglomerate masonry and where ramming is not employed is by far the most common, and is always found where brick or small stones are used for facings. These facings were doubtless laid one or two courses at a time and for the same purpose as the larger stones, to confine the fresh rubble and to form straight and true faces to the walls, which were afterwards veneered with marble or covered with stucco.

Some writers have assumed that the interior filling was mixed as concrete is now, and poured while in a semi-liquid condition between the facings, but Choisy demonstrates quite clearly that such could not be the method employed, but that layers of lime mortar, as before only from one to one and a half inches in thickness, were

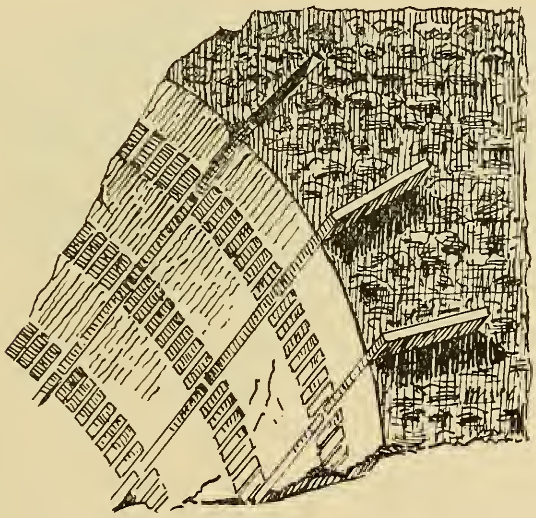


Fig. 4.

spread between the facings, and then the broken fragments were placed by hand and pressed down into the mortar. This is shown by the fact that the stones are always placed on their natural bed, and where pieces of pottery are used they are always placed with their faces following the horizontal plane, and again where fragments two or three inches thick are used, as sometimes occurs, it is frequently found that the layer of mortar spread over the top does not go down between these large fragments to meet the lower bed of mortar, thus leaving gaps in the vertical joints which would not occur in a mixed semi-liquid concrete, and which are seldom if ever found in the rammed work.

The triangular bricks used for facing such walls and confining the rubble were from one foot to twenty inches long, and from one

to one and one-half inches in thickness, and laid generally with very thick joints, often one inch in thickness, of lime mortar, generally with pozzuolana used in place of sand.

Often, in the earlier works, the faces of the walls were of small stones about six inches square on the face, and from ten to twelve inches long, and laid with diagonal joints forming what Vitruvius calls "reticulatum opus." Fig. 1, *b*.

In all these cases we see that the principal object of the brick and small stone facings was to confine the rubble work and protect it during the process of setting and hardening, while at the same time it was thoroughly incorporated in the mass of the wall.

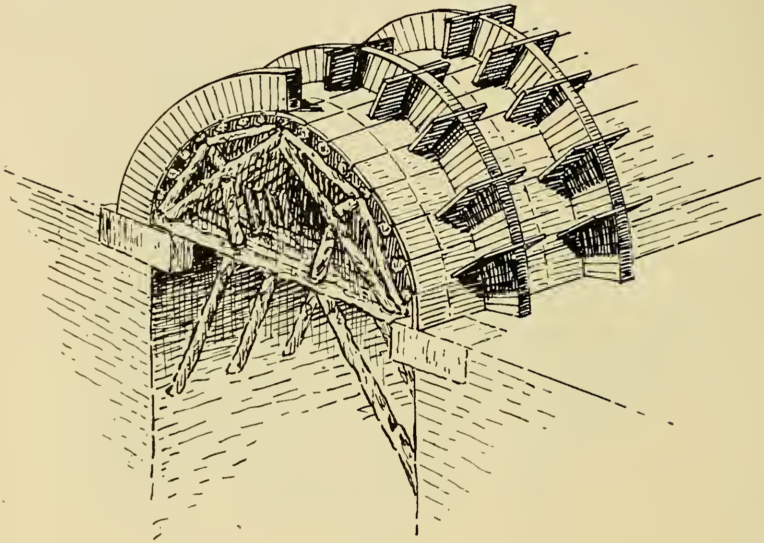


FIG. 5.

In this manner all expense and wastefulness of temporary curbing was avoided, and substantial walls were erected, largely with unskilled labor and with the commonest materials.

In building walls of this character it is evident that some method of bonding the two opposite faces at intervals should be employed, and this (Fig. 3) the Romans effected in two different ways. Often both methods were employed in the same wall.

In the first method sticks of roughly hewn wood were placed, extending entirely through the wall. Vitruvius refers to this method of bonding, and says in Chapter 5, Book 1: "The walls ought to be tied from front to rear with many pieces of charred olive wood, by which means the two faces thus connected will endure for ages. The advantage of the use of olive is that it is

effected neither by weather, by rot nor by age. Buried in the earth or immersed in water, it lasts unimpaired, and for this reason not only walls of cities, but foundations and such walls as are of extraordinary thickness, tied together therewith, are exceedingly lasting."

It is quite probable that these bonding sticks were allowed to project on both sides of the walls to support scaffolding for the workmen and materials, and, when the walls were finished, they were cut off flush with the face.

The wood has rotted out from all these Roman walls, but the imprint in the masonry gives proof beyond question of their former existence.

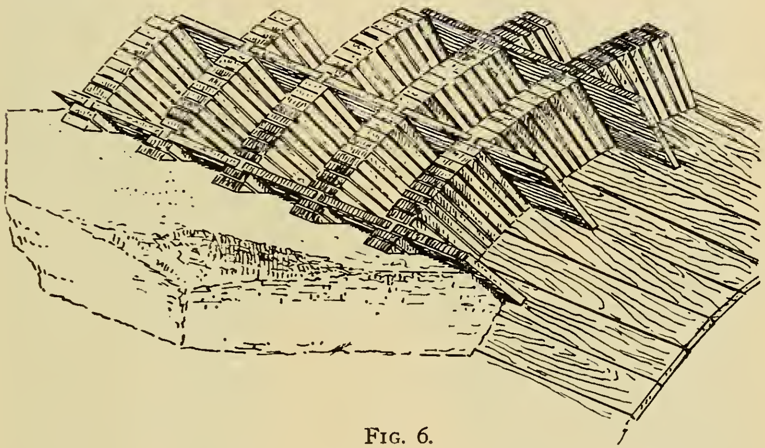


FIG. 6.

The second method of bonding, which has proved more durable than even charred olive wood, is also shown in Fig. 3. It consists of flat tiles of burnt clay, or large bricks, about two feet square, and from one and one-half to two inches thick. These are often used in single layers from four to eight feet apart, and sometimes with two or three courses together. This method of bonding is a strongly marked peculiarity of Roman walls wherever found in Europe.

But it is in the construction of vaults and arches that we find the ingenious method of the Romans carried to its greatest perfection, and the greatest saving of skilled labor and expensive materials.

While arches of cut stone with radiating joints were used by the Romans in their bridges, triumphal arches, city gates and some other monumental structures, rubble vaults were far more common and were built on a most stupendous scale.

These vaults, formed of small materials, were of infinite variety, and are found covering rectangular and polygonal spaces, rotundas and exedras; for, being, as it were, moulded, they could be adapted to the most varying forms, and could be made to meet all of the numerous requirements of planning.

The Romans may or may not have been the inventors of rubble vaults; that is to say, of vaults of small stones bound together with mortar, but it is certain that before them no one thought of constructing vaults of large span of such materials. With them it seems to have been developed during the latter days of the republic and the early days of the empire, or about the beginning of the Christian era.

The system developed rapidly, and the Pantheon is preserved to us, a masterpiece of the art and one of its earliest examples.

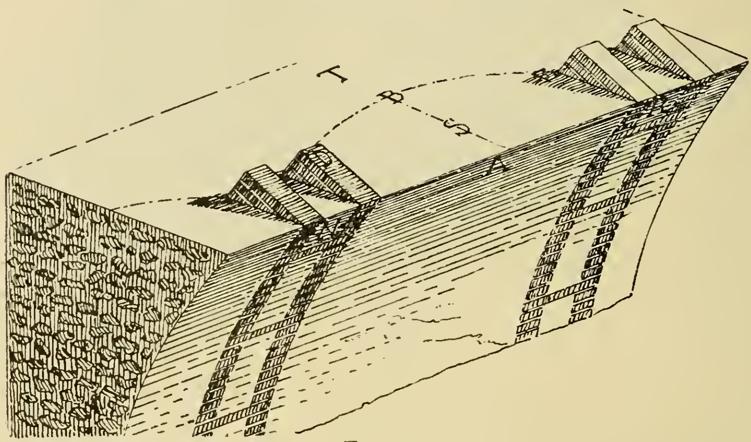


FIG. 7.

If one inspects an edifice vaulted with rubble, as for example the great Baths of Caracalla, he will perceive on the face an arch of brick with radiating joints, and behind these face arches a rough masonry similar to the interior of the walls we have described, but if one examines these masses of masonry more closely he discovers courses of an entirely separate construction imbedded in them, real ribs, sometimes entire networks of bricks forming skeletons in the body of the rubble.

This skeleton must not be considered as a series of relieving arches built at the same time as the rubble and intended to strengthen it. These arches of bricks in the Roman vaults were built first, with radiating joints and bonded to each other and to the face arches at intervals with large tiles, thus forming a complete framework which could be built on a light and inexpensive

centering, and which in turn supported the body of the arch as it was carried up with horizontal courses exactly as described for the walls.

Fig. 4 shows the appearance of such a vault with the facing bricks removed.

It is evident that the construction of wooden centering, of sufficient strength to carry such massive arches in a perfectly rigid

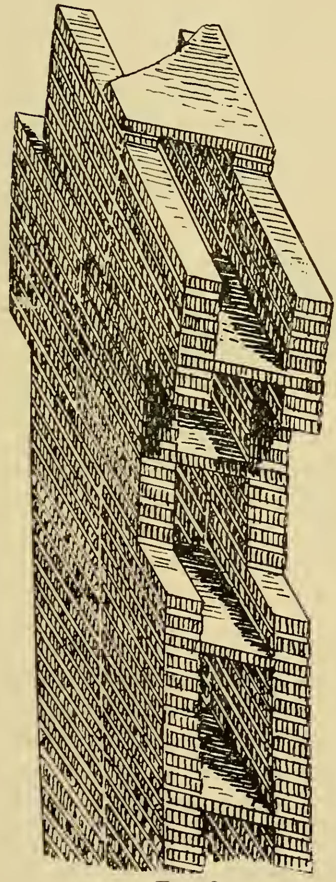


FIG. 8.

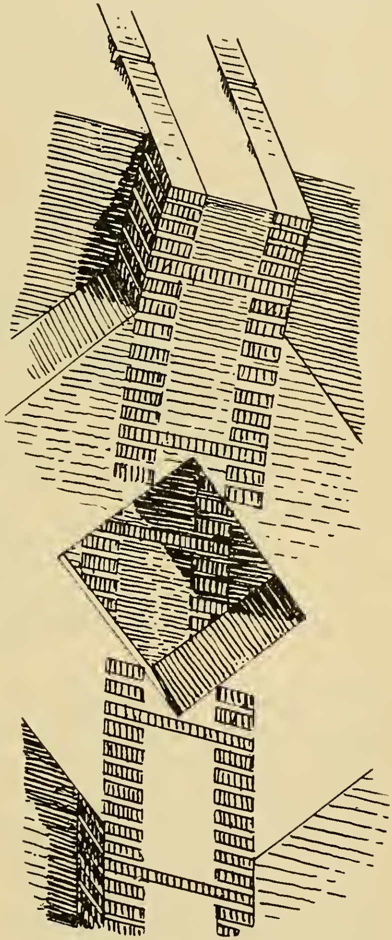


FIG. 9.

state while being built, would be a work of great expense and delay, requiring vast quantities of timber, considerable skilled labor and a great deal of time, all of which the Roman builders sought to avoid using unnecessarily.

Some centering indeed was necessary to support the light ribs of bricks on which to form the rubble. Such centering was con-

structed in as light and crude a manner as possible, generally of round or rough-hewn logs, supported on corbels of brick or stone projecting from the wall, roughly formed to the curve of the arch with bricks and earth, and, where necessary, further supported by vertical props. Fig. 5.

This rough centering was often paved with a layer of large, thin, burnt tiles, laid with open joints which would receive the rubble masonry and adhere firmly to it, thus forming the permanent soffit of the arch when the centering was removed. At other times it was covered roughly with boards which have left their imprint in the masonry of the arches.

The ribs or armatures of the arch were then turned rapidly and roughly, as is shown by their irregularity in many of the ruins. They were usually constructed with bricks about 6 x 24 inches, slightly wedged and laid in strong lime mortar. At intervals of

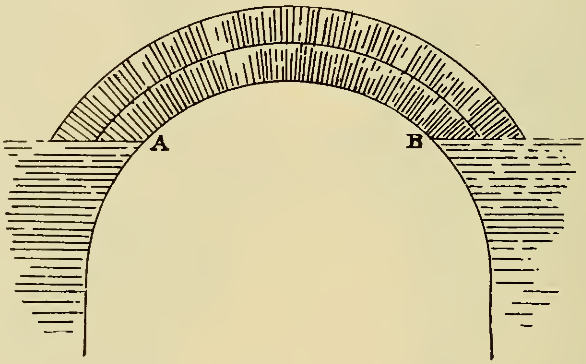


FIG. 10.

two feet or more large tiles or bricks about 24 x 24 inches were built in, forming wings, as shown in Fig. 5, or bonding the ribs together, as shown in Fig. 6.

At other times the ribs are built in pairs, with a space of eight or ten feet between them, as is shown in Fig. 7.

In still other cases, where very large arches were to be turned, as in the Basilica of Constantine, where they are about seventy feet span, these ribs were made double in height, as is shown in Figs. 8 and 9.

These light ribs of brick, once completed and bonded together over the rude centering, were of sufficient strength and rigidity to support the rubble work as it progressed, and were swallowed up by it, becoming thoroughly incorporated as a permanent part of the construction.

It is evident also that the work need suffer no delay while the

centering and ribs were being constructed; for, as shown in Fig. 10, the overhang of the walls was slight for about one-third of the height of the arch, and up to that height would cause little or no pressure on the ribs or centering, but it was necessary that the ribs should be completed before the work was carried higher.

Many barrel vaults of smaller dimensions were turned on armatures of two courses of bricks or tiles laid flatwise, the lower course laid continuous, of large bricks, and the second of smaller bricks covering the joints and forming blocks or bands as represented by Figs. 11, 12 and 13, the top course being laid in plaster or quick-setting mortar.

Of this type are many of the vaultings in the Baths of Caracalla.

When it came to groined vaultings, the Romans practiced the

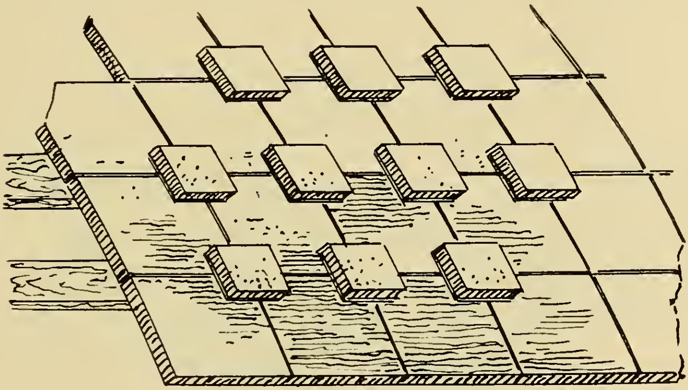


FIG. 11.

same economy in the employment of skilled labor and costly materials. It may be said in general that where practicable the Romans avoided the intersection of barrel vaults, but, where the requirements of the plan demanded it, they sought to make both barrel vaults of the same width, and where that was not practicable they usually stilted the narrower one so as to bring the top level with the large arch.

The centering and ribs were constructed in general as has been described for barrel vaults, but with the precaution of always having rigid ribs to form the groins (Figs. 14 and 15), or, if flat tiles were used, an extra course was laid long the line of the groin. (Fig. 16.)

In building circular domes the same elaborate system of ribs and skeleton armature was carried out.

The dome of the Pantheon, the largest, oldest and most per-

fect dome in masonry, and which some writers have described as of solid brickwork, others of solid concrete, proves by investigation to be of the fine rubble work we have described, with an elaborate system of ribs and arches incorporated.

Piranesi, the famous etcher of the last century, who devoted his life to producing in this manner the most perfect representations of the ruins and architectural features of Rome, made extensive investigations into the structure of the dome of the Pantheon while repairs were being made, and produced an etching of which Fig. 17 is a diagram.

The methods here presented are not the only ones employed by the Roman builders in constructing their vaults and arches. Many special devices were adopted as the difficulties and necessities presented themselves, and many combinations of different

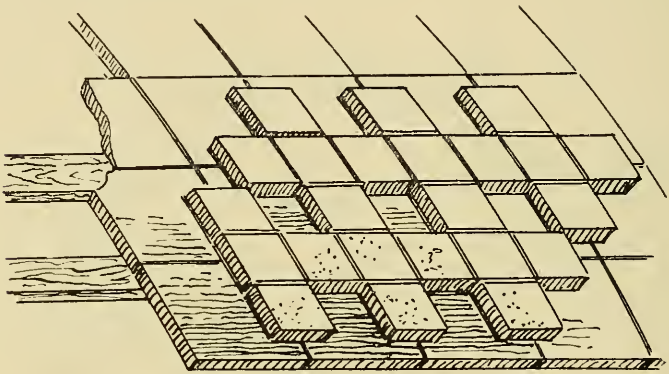


Fig. 12.

methods were employed, the object appearing to be always to prevent waste of valuable materials and skilled labor in erecting temporary and auxiliary works.

A study of these ingenious contrivances not only gives us an insight into the conditions under which Roman builders labored, but must increase our respect and admiration for their engineering and constructional ability.

Study of the ruins of Roman work indicates that the methods here described arrived at their greatest perfection during the first two centuries of the Christian Era, gradually falling into disuse and disappearing in the fifth century, after which few buildings of magnitude were erected in Rome until the days of the Renaissance, when the old Roman methods had been long forgotten, only to be investigated and comprehended in these latter days of the nineteenth century.

DISCUSSION.

President Molera.—When lime mortar is buried for a year or two in pits, it is supposed to absorb carbonic acid from the air, thus tending to return to its previous state of lime rock. The reaction takes place in the mortar itself. I suppose that in these large pits the covering was not such that it was hermetically sealed against the air, and that the air inserted itself into the mass. An analysis of the mortar in the ancient work of the Romans shows there is a great deal of carbonic acid in it.

Q.—Mr. Percy, as you have described the mortar with stones put in it, is it not something like our concrete? Do you know whether our modern concrete was known to the ancient Romans, and used by them?

Mr. Percy.—I think not. I think the method described by the writer I have quoted from so liberally must have been the one

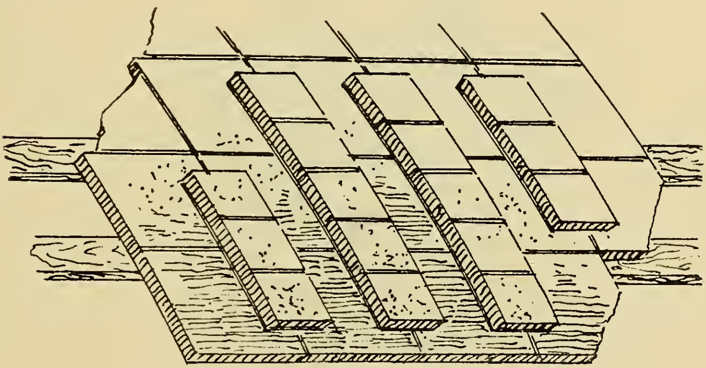


Fig. 13.

employed. If the materials were mixed together and put in as we put in concrete now, there certainly would not be any well-defined layers. He says that in large work it is in layers eight, nine or ten inches thick. Evidently the mortar was first put in and the stone was then rammed down into it, bringing the mortar to the top. The most common class of work is with brick facing. If the mortar had been poured in in a semi-liquid state the layers would not be so well defined. It is self-evident that the small stones or fragments of pottery were put in by hand, for they are always placed in a horizontal position. If they had been poured in they would be in all positions. Then, again, in these layers there is always mortar at the bottom, growing less as it comes upward in the course. The whole thing is logical when we consider that, in building a wall, common square bricks would not make a very good bond, but in such masonry the rubble filling with triangular

brick facings makes an excellent bond. There could not be a better bond devised than the triangular brick. This also would be an economical way of building walls, for it could be done with unskilled labor. It is very evident that the Romans had abundance of labor. They had great numbers of captives, and even their soldiers were put to work on these buildings and great structures. All sorts of labor were employed. It is apparent that this method was adopted so that a great amount of unskilled labor could be used in doing the greater part of the work, using skilled labor only for the finishing touches and the ornamentation. The ornamentation is of a Greek type, although the construction is Roman.

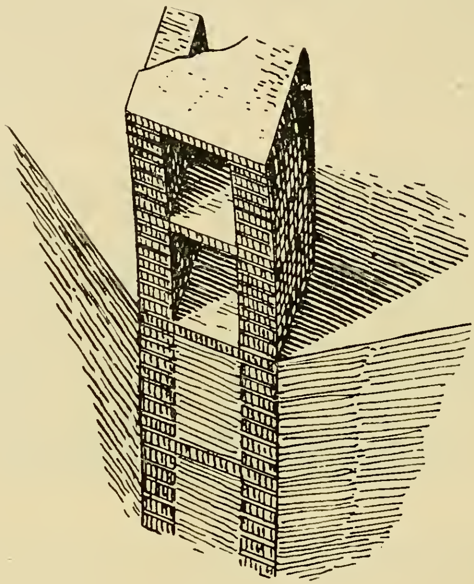


FIG. 14.

They brought Greek architects and Greek workmen to Rome to do this class of work. With this outside finish and ornamentation stripped off we now see the real Roman work and construction.

Q.—Do you understand this construction would apply to such buildings as the Colosseum and the great aqueduct?

MR. PERCY.—Yes, the Colosseum is of this method of construction, and of cut stone. The outer wall, and the second series of arches, and a good part of the third series are of massive cut stone, but the interior parts are almost entirely of bricks and of small fragments of stone and mortar. Perhaps it would be proper to call it rubble work; evidently the mortar and stone were put in by hand. It looks something like concrete, and it may be properly

called a fine rubble. The cut stone is travertine. Some of the piers and arches of the aqueducts are of cut stone. The piers and arches of the largest aqueduct in Nero's time, for instance, were of brick and rubble. A very interesting thing about it is that some of the arches proved too weak to carry the weight, and they have been reinforced by other arches built inside of them, and the piers have been thickened. The inner arches were built entirely of brick. A few inches were left between the crown of the new arch and the under surface of the old arch, and then on one side of the wall this place was bricked up, and this mixture of stone and bricks and mortar was rammed in from the outside into all the space between the two arches, thereby strengthening the original arches.

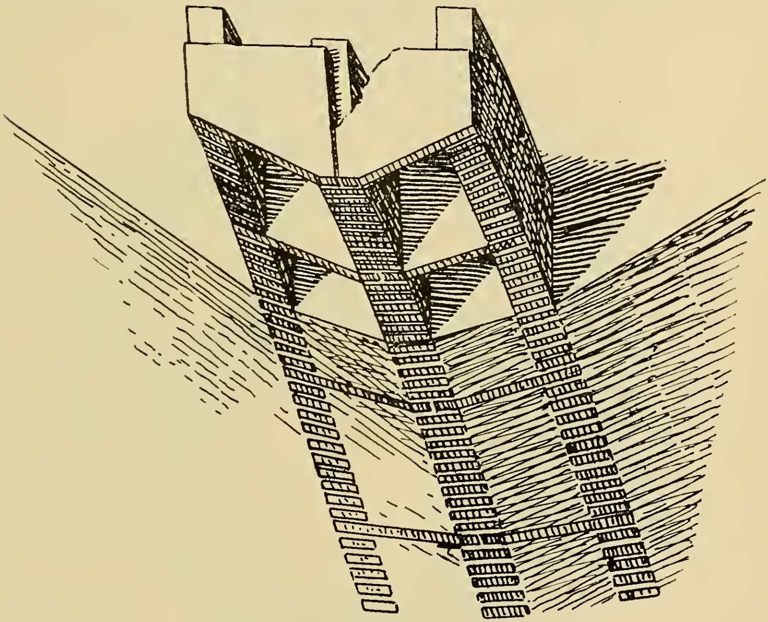


FIG. 15.

The Roman brickwork is generally made of thin bricks, often not over an inch in thickness. It is a very common thing to find the joints as thick as the bricks are. The mortar between the bricks has coarse sand in it. This is not intended to be seen, but to be covered up by the hydraulic cement I have spoken of, which also keeps the water from penetrating.

All the great arches, including the triumphal arches, were built of cut stone, and not of concrete and brick; also most of their gateways. The oldest Roman work is entirely of cut stone, and no mortar was used. The stones were fitted very closely to-

gether. About the time of Christ, roughly speaking, this method of using triangular bricks became the common method, and is particularly shown in those monuments built in the first, second, or third centuries of the Christian era.

The Romans at first used a volcanic tufa quarried on the site of Rome. It is not very enduring, and not very hard. All walls that were exposed were covered with stucco, both for appearance, I suppose, and preservation. As the Romans became more powerful, they wanted to build more enduring buildings, and they went to the foothills and mountains beyond, twenty-five or thirty miles, where there are excellent quarries of stone. You have a sample of this stone here in Golden Gate Park in the Keyes monument. That is Roman travertine. It is a very hard, enduring lime-

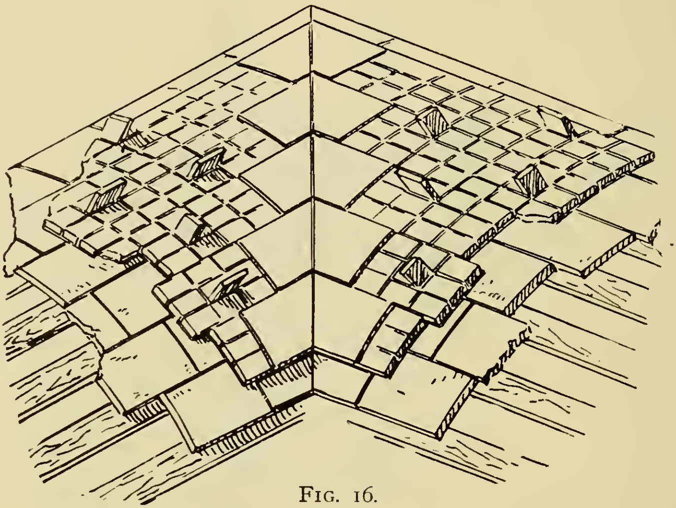


Fig. 16.

stone. The Colosseum and St. Peter's are built of that material. It was used very generally for building purposes. Temple building, up to the time of Christ, or soon after—such temples as the Temple of Saturn—are all built of white marble. In the first three centuries of the Christian era the Romans were not satisfied to use white marble, and they brought the richest and finest varieties of marble that could be found anywhere in Africa or Asia. The most of this marble has now disappeared, but fragments are still found.

The stone dug out of the catacombs was a soft tufa. I do not think any of the cut stone came from there, or that it would be practicable to quarry stone out of such narrow passages. The Romans probably made use of the tufa taken out of the catacombs, but they could not have quarried building blocks of stone out of

passages four and eight feet high and extending for miles in all directions. No sane man would take that method of quarrying stone, and certainly the Romans were logical people, as we have seen in the construction of their buildings. The catacombs, I believe, were made solely for burial places. The stone taken out is inferior material, at best, for building purposes. We find in this concrete or rubble work something of a guide to the age in which

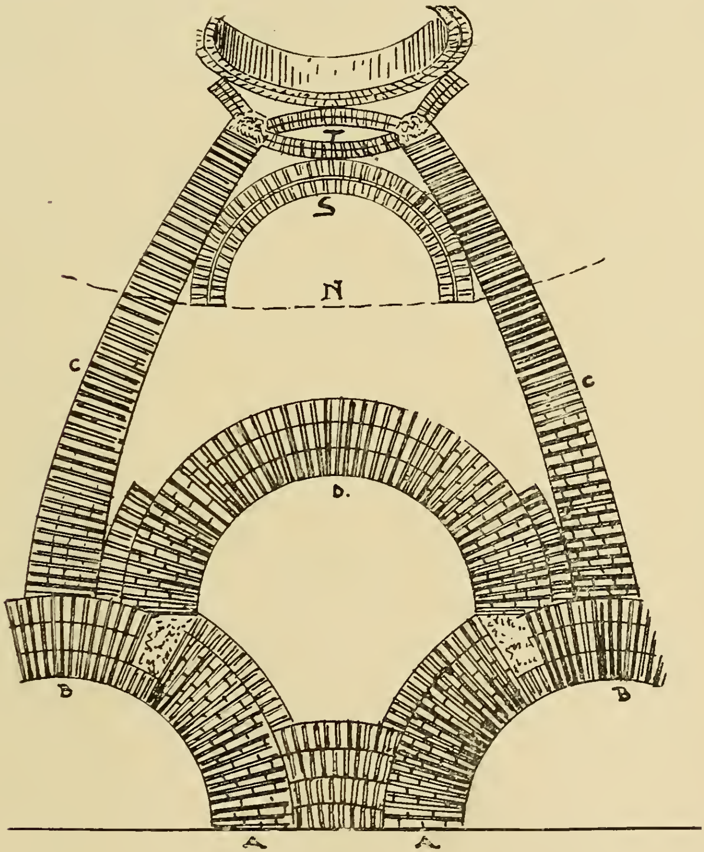


FIG. 17.

it was used. In the earliest work the tufa is the most common material in the concrete or rubble work. In a later period we find the travertine, and, still later, fragments of all kinds of marble, of chippings of marble, and of basalt and other stone, showing that the chippings from the stone they used for facing their temples all went into their concrete or rubble work, and nothing was lost or wasted.

I do not know of any granite near Rome, and yet we find granite used there in modern times. The church of St. Paul was burned in 1828 and has been rebuilt. There are a great number of very large columns, and they are of polished gray granite. Everything else is marble, but the columns are of granite. Where the granite came from I do not know. We find here the architectural works of the Greeks. They not only rubbed tne joints of stone together to a perfect joint, but even polished the joints. I do not believe there ever was such a waste of labor anywhere in the world as that. Unless I saw it I could hardly believe that such things were done.

IMPROVEMENT OF THE MISSISSIPPI RIVER DELTA.

The Louisiana Engineering Society is not responsible, as a body, for the facts and opinions advanced in any of its papers.

By Thos. L. Raymond, Member of the Louisiana Engineering Society.

[Read before the Society, March 14, 1898.*]

It is scarcely necessary to dwell upon the importance of this question at this time, for that is self evident, after the recent agitation of the subject before Congress by the public-spirited citizens not only of our own section, but of the whole valley of this great river, and in view of the expiration, in two or three years, of the contract for maintenance of the channel through South Pass by the Eads Estate.

A brief review of the methods which have been tried or suggested in the past for the improvement of the entrance to the river will be useful in this discussion, and these will be the better understood if we recall the conditions which have prevailed at and near the mouth of the river, as determined by the unmodified work of nature.

At a distance of twenty-five miles from the Gulf, measured along the channel, the river is 2700 feet wide, with a maximum depth of ninety-four feet. Just below this point the west bank was breached by a crevasse many years ago, and an outlet formed called "The Jump." It is twelve miles long, very narrow, only twelve to fourteen feet deep, and débouches into four feet depth in the Gulf, at a distance of seven miles from thirty feet depth. Another opening in the east bank is met seven miles below the Jump, and is known as Cubit's Gap. This may be considered as one of the mouths of the river, and it empties into the Gulf through a channel four to seven feet deep at a distance of nine miles from thirty feet depth.

Opposite Cubit's Gap, the width of the river has increased to 4100 feet, and its depth decreased to fifty feet; and this widening and shoaling progresses until the "Head of the Passes" is reached, where the width of the river is 6900 feet, and the depth thirty-three feet, in a channel entering Pass a l'Outre.

The river here divides into three main streams, viz: Pass a l'Outre, flowing about east; South Pass, flowing southeast, and Southwest Pass, named from its course.

*Manuscript received October 10, 1898.—Secretary, Ass'n of Eng. Socs.

Pass a l'Outre, before the work on South Pass was begun, was fourteen miles long and carried from the river forty-six per cent. of the whole volume of the river reaching the Head of the Passes. For the upper third of its length it afforded to commerce a channel 1500 feet broad and a least depth of fifty feet, but in its further progress to the sea this great volume was and is depleted by a number of outlets, two of which are of very considerable capacity, leaving in the main channel a volume of water which requires a width of 1100 feet and a depth of scarcely forty feet to carry it to the sea, while the rate of the current is so much reduced by this repeated lowering of the head or flattening of the slope that the depth over the bar was only about nine feet. During the last four years this deterioration has doubtless been augmented by the formation and enlargement of another great outlet known as Pass a l'Outre Crevasse, only two miles below the Head of the Passes.

South Pass, before Mr. Eads began the work of its improvement, was ten miles long, and carried only eleven per cent. of the total volume passing through the three mouths. The entrance to it from the river was divided into two channels by an island, while the main banks, widening out to a funnel shape to enclose it, had the effect of gorging the water entering the pass at its narrow throat, reducing the slope and consequently the current through the wider part above, and thus forming a bar across the entrance with only fifteen feet of water over it. For a short distance down in the pass, with a width of some six hundred and fifty feet, a depth of thirty-eight feet and over was maintained; but, below this stretch, the width, enlarging to 1100 feet to enclose another island, reduced the depth to thirty feet. Five miles below the head an outlet through the west bank drew off to the sea as much as twenty-three per cent. of the total volume entering the pass, with the inevitable diminution of depth to as much as ten feet less than what was found above. A short distance above its mouth a small outlet still further reduced its current and capacity, and finally, at a distance of one and a half miles from shore, the crest of the bar was found with a depth of only eight feet over it. Through a great part of its length the width of this pass is only six hundred feet.

Southwest Pass carried forty-three per cent. of the water in the river below Cubit's Gap. Its least width is about 1200 feet, and its channel depth varies from fifty to seventy-eight feet through twelve of its fourteen miles of length, and the shoaler two miles are at its mouth, where the banks widen out to the open sea. While this pass was being used constantly as the entrance to the

river the depth of the channel over the bar was usually about fifteen feet, but it has since shoaled to about nine feet.

Several methods have been suggested by engineers of repute for obtaining a deeper channel into the river from the Gulf than nature has provided. The first and simplest was by dredging through the bars by harrows, but this was soon abandoned, when the difficulties of working in the open sea were encountered, and when the action of the cross currents in refilling the narrow cut were learned by experience.

The second plan attempted to protect the channel by a sheet pile jetty on the east side and excavate under its protection. This plan succeeded in opening through Southwest Pass bar a channel eighteen feet deep, but the protecting wall was soon destroyed by storms, and the contractors failed to obtain the twenty feet guaranteed by them.

The third method was adopted by the United States Government about 1870, and consisted in stirring up the material composing the bar with large propellers, lowered to the proper depth, deflecting the surcharged water to the surface, and thus utilizing the strong current to transport the suspended material to deeper water. Two large and expensive vessels, built for this purpose, succeeded in obtaining eighteen feet depth by this method across Southwest Pass bar for a part of the time during three years, but the results were extremely unsatisfactory, as the channel was quickly obliterated by storms and was very narrow, and, as only the finer material was removed, the bottom became dangerously hard from the greater proportion of sand remaining.

The fourth method was that of flanking the mouths of the river by a canal with locks, connecting the deep water of the river with that of the Gulf at a point some thirty-three miles from the mouth. The object to be attained by this plan was the prevention of the bar formation by avoiding the constant flow of sediment-charged water through the entrance to the Gulf. This plan never reached a stage beyond that of surveys and estimates. It was the first suggested in 1832 by Ch. State Engineer Buisson, and was revived in 1870. The discussion of its merits, in comparison with jetties, was long and bitter, but after volumes had been written in defense of both projects, the jetty plan was adopted tentatively by the general government, on the guarantee of a private individual to make a success in South Pass.

Whatever may or could have been claimed for the canal in the early seventies was based on obtaining a navigable depth of twenty-five feet, considered at that time ample for the commerce of the

world, but, as the vessels of the present day require at least a thirty-foot depth, with the prospect of this being exceeded in the future, a glance at the chart will show that no safe navigation for such draft can be found through Breton Sound, which it was proposed to connect with the river by canal. Looking at this in the light of what has been accomplished by the jetty plan, it seems strange that a splendid natural channel of ample width and depth, with only four miles of shoal water dividing it from the deep basin of the Gulf, should be abandoned for ten miles of artificial waterway, limited in width and depth by considerations of cost, subject to the delays and uncertainties of lockage and finally reaching an arm of the sea difficult of safe navigation. For a vessel of thirty feet draft Breton Sound is not possible of safe navigation, and a locked canal between it and the river is not practicable at any reasonable cost.

The last and only successful plan was and is the jettying of one of the passes. This method of bar improvement has since the construction of those at South Pass, been applied, with numerous modifications and varying degrees of success, to many other harbor entrances in the United States. It aims to do suddenly, in the process of bank building, what the slow processes of nature accomplished only in centuries. Seaward of all harbor entrances the conflict of the littoral with the outflowing currents checks the movement of the sediment or sand carried by either, causes deposit and forms bars, the depth over which varies with the many varying conditions.

The Mississippi below St. Louis is a marvelous type of a sediment-bearing river, and it has been estimated that it annually transports to the Gulf a volume of solid material represented by a mass one mile square and two hundred and sixty feet high. The shoals which blocked the entrance to all of its "passes" were built up chiefly by the material carried out of the river, which is dropped by the current progressively as its rate is diminished with the widening of the distance between the banks, and more rapidly after the sea has opened its broad expanse to the flow. As is to be expected, the greatest amount of deposit occurs on each side of the thread of the current, though the western side of all the entrances built out the more rapidly, due perhaps to the sea currents being controlled largely by the prevailing winds, and also to the rotation of the earth from west to east, causing the deposit of a greater proportion of the drift and suspended material on the western side. The momentum of the current, the shoals on either side beyond the mouth and the head retained as far as the visible

banks extend, produce a current which is able to support and carry material some distance into the Gulf, and these factors regulate the distance from Land's End to the crest of the bar. The distance from thirty feet inside to thirty feet outside is, for Pass a l'Outre, three and three-quarter miles, for Southwest Pass four and one-half miles, and for South Pass, before its improvement, two and one-quarter miles.

As the process of bank extension progresses from year to year the rate of flow is maintained for a greater distance into the Gulf, carrying the material further and producing a yearly bar advance, which has been the cause of great doubt in the minds of many unprejudiced students of the problem as to the economic success of the jetty system at the mouth of the Mississippi. This bar advance has been estimated, by comparison of surveys extending over many years, at three hundred feet for Pass a l'Outre, one hundred feet for South Pass and two hundred and sixty feet for Southwest Pass, and the fear has been entertained that, with jetties completed, this rate might be greatly augmented, as much as four-fold having been claimed by some. This being, to my mind, the chief argument of value against the improvement by jetties, I beg leave to dwell upon it for a few minutes.

Briefly stated, the jetty system may be described as the extension of the banks of the stream out to sea as rapidly as possible by substantial structures built upon the shoals on both sides of the axis of the discharge channel and extending this confinement of the flow beyond the crest of the bar. The immediate effect of this sudden acceleration of the current across the shoals is to scour out a channel to a depth which is dependent upon the width of waterway between the jetties. This deepening may be carried to an indefinite limit, even to the undermining of the artificial banks which induce it, by contracting the width of discharge, or lessened to any degree by locating the jetties at greater distances apart. On the completion of the jetties the formation of a new bar is immediately begun, presumably at about the same distance from the mouth as was the crest of the old bar from the natural shore line; but this new formation is modified by several conditions. First, the head due to the confined waters, being transferred to the crest of the old bar, diminished only by the slope in the length of the jetties, produces a greatly increased velocity at the exit into the open sea, increasing the momentum of the outflowing volume, as well as the length of the slope to sea level, thus carrying suspended material a greater distance. Then, as the bottom slopes downward, instead of upward as with the natural mouth, the sedi-

ment, having increasingly greater distances to fall through a heavier medium to the bottom, is deposited at greater distances than when the upward grade of the bottom, as great as one foot in five hundred, rises at every foot to catch the descending particles. Lastly, the lateral distribution, by the immediate discharge into deep water, is unimpeded by the shoals extending on each side to the natural bar, and the littoral currents have opportunity for their maximum effect in distributing the bar-forming material over more extensive areas. The rate of the current, one mile beyond the end of the jetties at South Pass, has been observed to be as great as 2.8 feet per second.

Thus theory would indicate a slower bar advance, and twenty years of experience with the South Pass jetties furnishes the unimpeachable testimony of facts. Mr. Donovan, United States Assistant Engineer, in charge of examinations and surveys at South Pass, has studied this bar formation very closely, and the results of his observations are extremely interesting.

In the nineteen years between 1876 and 1895 the greatest fill observed directly in front of the mouth of the jetties was eleven feet, at a distance of one and one-quarter miles from the entrance, where the original depth was about seventy feet. Comparing the distances from the end of the jetties to certain depths which existed before and since the improvement, it is found that it is now necessary to advance about 1800 feet further into the Gulf to reach seventy feet depth than in 1877; or, in other words, the seventy feet depth has advanced by shoaling about 1800 feet in about eighteen years, but the forty feet depth has moved seaward only about nine hundred feet in the same time. The greatest fill is therefore taking place in what was originally seventy feet depth at a rate of about 0.6 feet per year. In the same time the one hundred feet depth has moved from a distance of 6500 feet to 8000 feet out to sea. It does not seem reasonable that this shoaling in deep water should be classed strictly as bar-advance, as applied to the movement of the natural shoal; for, should this shoaling continue at the same rate, thirty years and more must elapse before the shoaling will reduce the navigable depth to thirty feet.

Considering, then, the failure of all other methods of obtaining a deep-water channel to the Gulf, and that the jetties at a moderate yearly cost for maintenance have given commerce a safe and reliable channel for eighteen years for vessels of even greater draft than it was designed to accommodate, there should be no question, at this time, when a wider and deeper water-way is demanded by

the increasing size of merchantmen and war vessels, that one of the three passes should be improved by this method to the required capacity. The only point to determine is, which of the three should be thus improved.

At first thought it seems simplest and most economical to increase the depth and width of South Pass, utilizing the work already done. There are, however, serious, and to my mind fatal, objections to the accomplishment of this. It will be admitted that the only means by which the Pass can be economically enlarged is by diverting more water into it. To do this it is necessary to increase the head of water above it, and prevent its seeking other routes to the sea, by partially damming other outlets and forcing it to take its course by the unobstructed pass. Any desired increase of volume could thus be added to South Pass, but when it is remembered that the scouring which would result would attack the banks as well as the bottom, it cannot be doubted that such a course would be hazardous. The banks of all these passes are perilously narrow in certain parts of their course, and only solid enough to afford a footing within a few feet of the edge, while the tide ebbs and flows over the sea marsh behind. So unstable are they that it is almost certain that they have settled an appreciable amount in the past twenty years under the weight of deposits yearly formed upon them. To increase the width of South Pass to much more than six hundred feet, which it affords now, would court the danger of a crevasse like that in Pass a l'Outre and the consequent destruction of the channel below it.

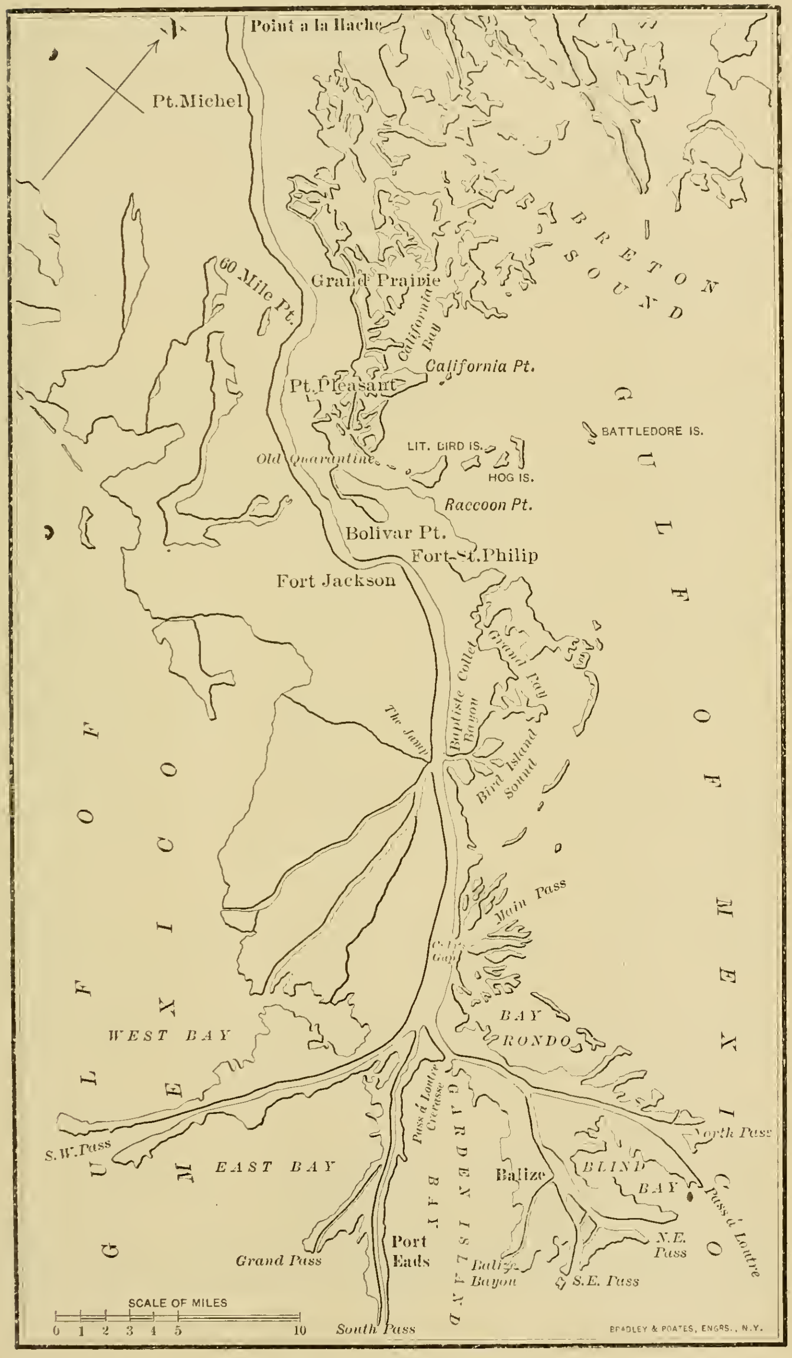
The jetties were built one thousand feet apart, and nine hundred feet of water-way is the most that could be obtained between them. This would involve the removal of wing dams and the inner parallel jetties built to maintain the present depth, while the danger of undermining would extend to the original jetties. These seem sufficient reasons for abandoning the attempt to enlarge South Pass beyond its present dimensions, aside from any considerations of cost. So deeply was Mr. Eads impressed with these possibilities that he seriously contemplated preventing its further enlargement at one time by throwing a sill across its head. If all repair work upon it were stopped now it would still, for years to come, accommodate all but the larger vessels entering the river.

Pass a l'Outre, for the upper third of its length, offers a sufficiently wide and deep channel to warrant the improvement of its bar, but below Southeast Pass, one of its outlets, its cross-section rapidly diminishes. This involves not only the closing of that outlet and of the more recent crevasse, at great expense, but it

means also the consequent shoaling, after this is accomplished, of this upper stretch by the diminution of its slope and the resulting check to the current. The enlargement of the lower stretch would certainly endanger the banks also, though to a less degree than in the case of South Pass. At the mouth, where two channels now exist, one of them would have to be closed by expensive works, and then, with these improvements to the pass itself, the jetties over the bar could accomplish a result incomparably better than could be obtained in South Pass.

We come now to the consideration of Southwest Pass. Recurring to what has been already said, it will be remembered that with a least width of 1200 feet, it carries a least depth of fifty-two feet through twelve feet of its fourteen miles of length, which is at least ten feet deeper than is found in six miles of Pass a l'Outre. It has no outlets of consequence from head to mouth, and its course is almost straight. The distance from Land's End to the crest of the bar is greater than that at Pass a l'Outre, but the course of the single channel across it is flanked by shoals with a maximum depth of nine feet, upon which jetties could be built. Finally, the improved channel at Southwest Pass would be sheltered from storms from any direction east of south, and, as few, if any, violent winds blow for any length of time from west of south, the harbor immediately inside of the jetties would be amply protected, and the channel less liable to injury than that at Pass a l'Outre, which opens out nearly due east. The most important of all these advantages is that of the great depth throughout the pass itself. The slope of the water surface, which, for a given cross-section, governs the rate of the current, is determined, of course, by the fall from the head of the pass to the Gulf level, and by the length of the pass. The Gulf level at the lower end is constant, within the limits of tidal oscillation, and the height of the river at the head of the passes is fixed at a maximum by the height of the banks. The maximum head of the river in flood stages at the Head of the Passes is about 2.5 feet, giving, for Southwest Pass, that much fall in its length of fourteen miles, less the small amount in the open sea. Should the pass be lengthened by jetties four miles, equal to twenty-eight per cent. of its present length, the slope and current would be proportionately reduced, and the pass would immediately begin to shoal to accommodate the new conditions.

In the case of South Pass the closing of outlets tended to produce a shoaling above them and a deepening below, while the lowering of the head by Pass a l'Outre Crevasse also caused a



THE MISSISSIPPI RIVER DELTA.

shoaling. Hence that due to the increase in its length alone cannot be ascertained. Before the break in Pass a l'Outre, however, a shoaling as great as fifteen feet had occurred in the deepest parts of the channel above the old outlet, and as much as eight feet below it. It is therefore essential that the original available depth in the pass to be lengthened should be as great as can be found, to allow for this certain shoaling. Southwest Pass, having, below the Head of the Passes, a least depth of fifty-two feet, affords ample allowance for this deterioration, while Pass a l'Outre, for six miles of its length, has a depth but little greater than that required for safe navigation.

In the absence of data furnished by detailed surveys, of course I have not presumed to estimate the cost of this improvement, but, remembering that the South Pass work cost the government $5,250,000; that experience with work of this character has largely reduced its cost; that the materials, such as brush and stone, could be obtained now at but little more than half the prices paid then; that much of the expensive work at the Head of the Passes would not be required for Southwest Pass, and that enormous rates of interest were paid for the use of money in a work of doubtful success, it cannot be doubted that, even with the greater work required for the greater pass, the cost would be much less. At Sabine Pass, to July, 1896, the two jetties, aggregating 34,000 feet in length, and of depth gradually increasing to sixteen feet, had cost $1,815,000, this including considerable dredging. Some 12,000 feet of this work was built in depths of nine to sixteen feet, and the construction has been done under small contracts extending over a period of sixteen years, adding greatly to the cost.

Southwest Pass jetties proper would have an aggregate length of about 40,000 feet, but the substantial work could be located in depths not exceeding nine feet, except at the extreme sea end, and lighter and much less expensive construction utilized to reduce the width as required, thus bringing the cost down to a sum comparable with that expended at Sabine Pass.

If what I have said in comparison of the three Passes is admitted as just, then the conclusion is inevitable that Southwest Pass is best adapted to the needs of navigation, and that the removal of its bar by the jetty method will afford the most advantageous, capacious and enduring water-way, with a width of fully 1200 feet, and a depth of at least thirty-five feet in the navigable channel.

MUNICIPAL CONTROL OF PUBLIC WORKS.

The Louisiana Engineering Society is not responsible, as a body, for the facts and opinions advanced in any of its papers.

By H. J. Malochee, Member of the Louisiana Engineering Society.

[Read before the Society, May 9, 1898.*]

Among the great changes which in the last few years have taken place in the distribution of population in this country, and, as a matter of fact, in the world, none has attracted the atttention of the political economists more seriously than the increased size of the cities. With this and other changes have come, and must come, corresponding changes in the law governing the two component parts of the state, the town and the country,—changes not only in the organic law itself, but in its practical application as well.

And in this practical application, in the urban life of to-day, in its comforts, health-giving improvements, rapid transportation, etc., the duties of the engineering profession are certainly on a par with those of any other professional calling, and the knowledge and advice of its members are in constant demand. Therefore, it is but natural that we should find ourselves discussing the question of municipal control of public works at this meeting, especially when we remember the active discussions which this subject has brought forth during the last few months in our own city.

Municipal control of public works does not necessarily imply ownership or operation,—yet this question is seldom discussed or even referred to, unless either one or both of these conditions are mentioned or insisted upon. Why should this general demand exist for municipal ownership or municipal operation? Why should such a number of good citizens organize in order to secure it? Possibly the answer to these questions is that, in the past, the means used by corporations to perpetuate their municipal contracts were such as to cause, at this late day, this general demand or this organization of citizens. Again, the desire of political power, or other selfish ends, might be the motives which prompt such movements.

The engineer, as a citizen, may or may not wish to deal with these conditions or with their causes, but as an engineer, adviser or designer, it becomes his duty to take into account all the conditions and circumstances which might affect the subject under consideration. Therefore I believe that if we are to consider this

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question from the engineer's standpoint, all possible scope must be given to the discussion and every point pro and con can be and should be taken and duly considered.

In order to arrive at a general idea of the subject under consideration, let us paüse and see the extent of the works which should be under municipal control; let us note their importance and the general method of construction and operation necessary to arrive at the best results. It is an obvious fact "that the science of city government includes administrative science, statistical science, engineering and technological science, sanitary science, educational science and moral science." Of these various branches of science none is more important, and surely none strikes home into the heart of the masses surer and deeper than that which deals with those public works which are in charge of the Engineering Department. Public works, as generally understood, include good roads for both streets and sidewalks, drainage, water works for drinking, washing and flushing purposes and for fire protection, sewerage, street cleaning and disposal of garbage, wharves and docks, belt railroads, parks and public squares, public lighting, street railroads, intercommunication systems by means of telegraph, telephones, etc. No one will question the great importance of all these works to the public at large, nor will anyone doubt that the government ought to have such control over the services as will, at all times, compel those in charge to maintain and operate them so that they shall be considered public benefactions instead of public curses, as has been the case in more than one unfortunate municipality.

All public works involve engineering ability of a greater or less degree, and that means, in the broadest application of the phrase, designing, planning, execution, all with one end in view, that of reaching a certain result. As a rule, any result can be attained, by using any one of several different methods, and the fact that by the method employed a given result is attained in a more or less efficient and cheap manner determines in a great measure the ability of the engineer. The man who designs is best able to have his design executed properly, and therefore when large works, covering a period of several years' construction, are contemplated, the designing engineer should be, under ordinary circumstances, the one charged with their execution.

I maintain that this is the fundamental principle which should govern any legislation or any scheme which has reference to public works, their construction, their maintenance, their operation. As all public works are more or less part and parcel of one general

scheme which has for its aim the comfort, convenience, safety, health and general welfare of the people, each particular department must be in accord with every other department, and all improvements and suggested changes must needs be in accord with the different parts of the general scheme which go to make up a grand, magnificent, efficient system—a unity.

And how can this be attained surely and safely, if not through the agency of a permanent corps of competent engineers and assistants?

The necessity of having a permanent organization to conduct any commercial enterprise has long been recognized, and it is strange that the people of this country, with all their well-known ability in trade and commerce, have not, to this day, understood this with reference to the municipal officers charged with the details of administration, design and operation of the commercial part of their municipal governments. It should have been recognized by the people years ago that permanent works, improvements which are to last several generations, must be evolved, constructed and maintained by a permanent organization, one which is not and cannot be disturbed on account of politics, or any other reason, except incompetency, malfeasance, corruption in office, and kindred crimes.

The permanent character of the organization charged with the details of the controlling power being recognized as necessary, the next step to consider is how to arrive at this result and obtain the best service for the least money. As the Mayor of Toronto recently said, while discussing the question of municipal ownership of water works in that city, the whole question "is a matter of business." If a city can get as good a service *in every respect* under one system as it can under another, yet obtain this service at a cheaper rate, then the cheaper system should be used. I say, in every respect, because the cheaper system might not be the best, as various objections, scientific, political and otherwise, might be inherent to the cheaper method.

Of the various plans adopted or suggested in order to arrive at correct municipal control of public works, the following might be considered as the most important, either on account of their extensive adoption, their novelty or their excellent points of recommendation:

First. We might mention the one probably most extensively used in this country, that of farming out privileges to private individuals or corporations for money or other consideration, the

municipality reserving its rights of police power and of party to the contract, but having no further control over the contractor.

Second. The slight improvement on the first plan, secured by injecting into that system such control as the right of executive officers to examine the books of the contractor, restricting dividends to a certain amount, the balance of profits being applied to a reduction of rates, to a division between the municipality and the contractor of the surplus, and so forth.

Third. The system by which the municipality builds, owns and operates all works through its executive officers.

Fourth. The leasing to contractors of the various works which belong to the municipality, the latter thus owning and, in some cases, maintaining the works, but leaving the risk, details and profit of operation to the contractor who pays a money consideration or a portion of the gross revenue.

Fifth. The placing of all common carriers and public servants under State Boards of Control, in the same manner as the Commonwealth of Massachusetts placed all the lighting companies under the control of a commission, with enormous powers for the regulation of rates, etc., thus placing safeguards around its corporate investments under which the right of the public and the rights of invested capital are both secured.

Sixth. The placing of all municipal works in the hands and under the control of a Board of Public Works, whose supervision embraces the construction, maintenance and operation of these works; this supervision being in some cases absolute, coming direct from the Commonwealth, and in other cases being such as to be partly under control, the Board of Aldermen having the final approval of plans involving extensive expenditures of moneys.

Seventh. The system that is used in Indianapolis for the control of natural gas supply or such a modification thereof as is thought best under the local conditions and laws. This system involved the creation of a self-perpetuating board of five trustees, who held no stock in any competing company, and whose selection was made with great care, so as to secure persons whose character and public spirit were such as to constitute a guarantee of good faith and business-like management. The subscriptions for stock in the company were received only upon the subscriber entering into a special contract, by which he named the trustees as his agents and as holding an irrevocable power of attorney to vote the stock subscribed for by him in elections for directors, and further, as soon as the holders of the stock or their assigns shall have received the

face value thereof, with eight per cent. interest, the service charges must be reduced to cost.

Each of these systems has its merits and its defects; and, strange as it may seem at first, the system best suited for one class of public works is possibly not suitable for another class. Again, under different local conditions, the same character of control might not be applicable to the same class of public works; yet it can be assumed, without fear of being contradicted, that in all cases municipal control is necessary; this premise is hardly debatable, but—what kind of control? As far as water works, drainage, sewerage, paving, wharves, docks, belt railroads, parks are concerned, it is doubtful whether municipal control in the shape of actual ownership and operation is even debatable, but municipal ownership of gas and electric light plants stands certainly on questionable grounds, while few, if any, think of street railways as fit subjects for either municipal ownership or municipal operation.

In discussing the several systems mentioned above, it is well to remember that all public works, more or less, use the streets of the municipality for the purpose of distribution, and, for that reason, if for no other, the streets must forever remain the free and absolute property of the municipality. Possibly this ownership of the streets might go so far as owning the various systems of distribution above and below ground and deriving rental from their use, although it is a matter of considerable doubt in my mind whether such ownership is always advisable.

It should not be forgotten either that there is a great difference between various so-called public works, in so far as the nature of the distributed material or energy in concerned. Water is a natural product, one which has no substitute, whereas gas, electric light and other such commodities are manufactured products, for which substitutes exist. In one case only distribution is required, whereas, in the other case, all of the risks, details and expert service necessary in factories of that character are required.

As a discussion of any of the various plans mentioned above would involve some points of interest in each of them, it is probably better to discuss them generally under such a caption as "Objections to Municipal Ownership and Operation" of the various classes of public works, while taking pains to bring forward the advantages as well as the disadvantages of each particular system for each particular class.

Taking the class of works which ought to belong to and be operated by the municipality, it is clear that, if the advantage of permanency in the technical corps in charge of such work is ad-

mitted, then there is no possibility of believing that these works can be safely left in charge of the executive officers of the municipality who are elected to political offices by political parties whose sole aim is the reaping of the benefits of the spoils system; therefore, the only systems of control admissible would be restricted to the last three, viz: control of existing corporations by public commissions; construction and operation by Boards of Public Works; or a co-operative system of public ownership, such as the Indianapolis system. But the question might well be asked, why should these systems be owned, and if owned, why operated, by the municipality? These works can be classed as natural monopolies brought about by the fact that the interests of the many are at stake, that the expenditure of millions is required for their establishment, and that little, if any, competition can be reasonably thought of in connection with the operation and maintenance of such works as water works, sewerage, drainage, belt railroads, parks, etc. These works are the results and the necessities of our urban life, necessities which are, in their nature, either the simple distribution or destruction of natural products, or they are requirements of trade which must of necessity be free to the people, or whose use must be so unencumbered that the municipality's right of ownership and control shall never be questioned.

Then again, the public health, as well as adequate fire protection, are to be considered, and if these matters are left to a contractor, then upon him partly devolve responsibilities which ought to belong directly to the government; responsibilities which, in a great measure, are part of the police power of the municipality, that power which has served as the key to many a serious and difficult situation.

If the privileges for these works are sold, or if their operation be leased to contractors, the rights of the two contracting parties must be protected; and, as contracts generally extend over a period of years, and as annulment of contracts are at best not easily secured, the changes necessitated by the rapid advances of the age, by the increase of population, by the demands of trade, must suffer either by waiting for more propitious times when the contracts shall have expired, or by being paid for at enormous advance over the real value of the improvements.

But the objections to the municipal operation of these so-called natural monopolies are not easily overcome. The organization necessary for this operation is as an army of office-holders, which stands like an insurmountable barrier to the will of the voters, one whose power can be broken down only by a revolu-

tionary uprising of the people. The government employe is always apt to believe that less is expected of him than is expected of the employe of any other corporation; and, notwithstanding our desire not to ventilate these facts, it happens very often that the incompetency of municipal officers is so patent as to evoke surprise even on the part of persons entirely unacquainted with the character of the work for which these officers are employed. The technical and commercial results attained by municipal plants are not generally of such a character as to warrant the risk and expense. All these objections might be true, and, if the proper precautions are not taken, they are bound to come true, but it is also true that various plans have been proposed and have been actually tried for years, by which all these objections can be overcome, whereby no political party shall be actually formed by the office-holders as against the tax-payers and other citizens, whereby the best talent can be secured to take charge of these works, for the reason that the permanency of the positions offered is assured to the office-holders and that no levy on their salaries will be made for election expense funds and the like.

Such systems as are used in Europe, where the efficiency of the municipal service has reached a maximum, mainly through the appointment of the most competent men to hold offices which are practically for life, through the expenditure of almost incredible amounts of money to secure the proper service, and by means of a system of civil service unknown to this country,—such systems, as well as others used in this country, have absolutely taken out of politics those public works which should be under the complete control of the municipal officers and have brought these services to a state of perfection which is astounding.

As to the other class of public works, which is said to be on questionable grounds, their ownership and operation by the municipality is not so easily discussed as the previous class, nor is a decision arrived at without considerable study of conditions, local as well as general. This question might well be considered under the following general headings, viz: The legal right of the municipality to engage in that sort of business; its moral right under existing circumstances; the expediency of that method of control. In discussing the legal right we would be expected to consider the terms of the charter of the municipality, its powers and duties as conferred by this charter, and therefore we must refer this part of the question to those versed in the laws which have reference thereto, and we now pass to the morality of the act.

The existence or the absence of a company engaged in the

business, holding a franchise from the municipality, changes the question of moral right very materially; so also is it changed according as the establishment of a plant for municipal use alone, or for municipal use and commercial supply is under discussion. The expediency of the installation of a municipal plant is dependent upon the legal, moral, financial and commercial aspects of each case, and can hardly be determined except by a general consideration of all the reasons for and against these particular views of the subject.

Examining the moral reasons in favor of and against the establishment of a municipal plant under the various aforesaid conditions, it is first to be noted that, at the time when the franchises for many public works were given, the establishment of these plants was accompanied by a greater risk than the average business should entail; in fact, a grave doubt existed in the minds of many well-posted advocates of these industries as to their ability to pay. Now, where a municipal plant is to be installed, if the city has, by direct or implied contract, caused the existing company to make such investments as were necessary to supply the city's wants, then this direct or implied contract carries with it at least a moral obligation to either purchase or pay for such apparatus, or so arrange matters that the company will not lose the capital so invested. This would be the moral aspect in the event that the city plant was to be used for city lighting alone, but where the city plant was intended to supply also commercial lights in direct competition with the already established plant, then it would surely be generally considered dishonorable in the extreme, for the reason that by such proceeding the entire power of the city would be used to compete with a part of itself, and that such action would tend towards the impairment if not the destruction of the capital invested in an enterprise which it had fostered and encouraged.

As previously stated, the expediency of the method of municipal control by the ownership and operation of public works is determined by the fact that the action contemplated is legal or illegal, moral or immoral, financially successful or commercially disastrous. As a general proposition, that which is illegal or immoral is inexpedient, and that is particularly true of a community at large; thus, the legality or immorality of an action would, in a great measure, determine the expediency of the municipality's actions with respect to the control of its public works.

To determine whether the proposed installation shall be a financial success or loss, we must first take into consideration the various plans proposed, and submit each individual case to one

thoroughly competent to make the necessary correct estimates; one who shall take account of every item, large or small; one whose estimates shall not be guided by his sentiment and prejudice. It is then necessary to compare the conditions existing, and especially those apt to alter these estimates, in the light of previous experience by careful comparisons between the proposed and already established plants.

One of the arguments used assiduously by the managers of existing plants is one mentioned previously in reference to the comparatively small amount of work done by municipal employes, and the relative incompetency of these employes; but this is generally incorrectly stated in such a way as to appear as though it was impossible to have faithful and competent men in the public service. Such men may be got by the municipality, but such is not the good fortune of many municipal governments; and, further, even when these services are secured, these men, after a time, become generally lax in their duties. The experience of the average municipality is that less work is done by its employes, simply because it becomes a custom among them to do less than they would be expected to do for any other corporation. In fact, they consider themselves privileged characters, whose positions confer on them certain rights over and above the rights accorded to other persons in similar positions.

The third class of public works, which are seldom considered as fit subjects for municipal ownership, must yet under all circumstances be under municipal control. Taking as an example the street railroad, we first find, in large communities, innumerable parallel lines, lines which have little if any reason to exist, lines which mean the duplicating of investment without any real benefits being derived therefrom by the traveling public; in fact, whose duplicating has been in many cases a source of poorer rather than of better service.

Then we note the question of improvement of equipment, reduction of fares, etc., all of which are discussed without special knowledge of the circumstances and without regard to the justness of the demands. Public investigations are held by committees of men without experience in the details connected with the operation of such works, often without any well-defined idea of the public requirements; the publication of these investigations is read by men able to examine them only through the lens of a biased mind, or by others who are entirely unacquainted with the methods necessary in handling large financial schemes, and the result is a still greater separation between the public and its servant corpora-

tions, until the time comes when all the rights of these corporations are so abbreviated as to force them to the wall and a complete annihilation of the capital invested is arrived at.

It seems reasonable to suppose that the best method in cases of this kind is that regulation of all complaints and evils by a system of control such that the general methods of government of these corporations are known to the public at large, being made so through reports to properly constituted commissions, it being understood that all minor details are eliminated from these reports, yet are subject to private investigation by the commissioners, and that the decision, and not the evidence in each individual case, shall be published. If the characters of the members of these commissions are such that their decisions carry weight and confidence, and that their motives shall never be questioned, then the solution of the major part of the difficulty is within the reach of those who desire it; then the people and the public servants will be brought into a closer bond of friendship; then the corporate as well as the public interests will be protected and the desired end reached.

The regulation of public corporations by trade competition has been tried, but such method has generally resulted in several evils, such as duplication of equipment, with its increased capitalization and increased cost of operation, combinations of interest and consequent advance in prices, division of territory with the same general results, demoralization of the municipal officers through the endeavors of the competing corporations to secure favors at their hands, and many more objections which are more serious than the ones due to a monopoly, even if that monopoly has no restraint placed upon it by proper municipal control. Thus we come to the conclusion that, in so far as concerns that class of public works wherein the service is extensive yet personal, the employes numerous, the labor of high grade, the management technical,—such service as that of street railroads,—it is much better in the hands of a private monopoly, whose franchise is perpetual, whose operations are controlled by a commission representing the municipality's best interest; all this, coupled with a system of perpetual profit-sharing with the city, joined with a remission of charges whenever the profits come to be sufficient for the purpose.

A careful consideration of the foregoing will prove that *each* class of public works must be controlled in a different manner, and that, under varying conditions, the method of control will not be the same. Another thing proven is that technical matters should be handled by men whose special knowledge eminently fits them for the position they fill, and therefore that politicians should not

have the naming of the officers who occupy technical positions. It is also proven that these men should have permanent positions, thus combining several advantages, such as uniformity of design in the general plan, correct understanding of the details involved in the general design, ability to devote entire time, talent and attention to their duties without being called upon to make combinations with politicians in order to retain their positions, thus causing in them a feeling of dependence and subserviency, which would produce a warping of their judgment by considerations which ought never to be allowed to enter the minds of technical officers.

The examination of technical reports, the study of problems for the betterment of the public services, the necessary investigation to determine whether such betterments are possible, the reports on subjects relating to details in the management, the tests necessary to ascertain whether contract obligations are being carried out in conformity with the contract; in fact, almost everything that relates to public works is, as a rule, referred to the engineering department for a decision and report as to facts, technicalities and advisability, thus placing the responsibility of control in a very great degree upon the municipality's engineering staff. This responsibility proves that the opinions of engineers on the subject of municipal control of public works are entitled to more weight than those of the average citizen; that legislative schemes which do not embrace their ideas on the subject are apt to be incomplete or unsatisfactory in the end; and as this Society is the authoritative organ of the engineering profession of the State of Louisiana, it therefore becomes its duty, as representing one of the professions most interested, to express itself on this important subject, which is now occupying the attention of the Constitutional Convention and of our community.

Let this expression take whatever form the members think best, but, in justice to ourselves and to our noble profession, let it be scientific, technical, honest and true, and when the perfect control and regulation of municipal works shall have increased the healthiness of our already healthful surroundings, paved our streets, increased and bettered our water supply, improved our drainage, secured to our city the commerce to which she is entitled, —when all these permanent improvements, which will go to make up the jewels of her crown as queen city of the richest valley in the world, shall have been secured, then will the future generations who will enjoy and reap the benefits of all this work forever sing the praises of those whose combined efforts shall have made those superb achievements possible.

SULPHURIC ACID AND THE BY-PRODUCTS FROM IRON PYRITES.

By R. G. Ewer.

[Read before the Detroit Engineering Society, February 19, 1897.*]

Before describing the present mode of manufacture of sulphuric acid it may be well to give a hasty glance at its early history.

Basil Valentine, of Erfurt, Prussia, born in 1394, was the first to mention sulphuric acid, and his writings show him to be well acquainted with its preparation and use. There is evidence, however, that it was known a long time previous to this.

Sulphur was used in the time of Pliny for making matches and for bleaching purposes, by being burned in a current of air.

An Arab named Geber obtained sulphuric acid by distilling alum in the eighth century.

Although acquaintance with sulphuric acid began so early, it was not until 1570 that anything like a correct description of it was given. At that time such a description appeared in the publications of Gerard Dornæus.

Sulphuric acid is found naturally in many springs in connection with volcanoes, and in these cases is without doubt derived from the burning of sulphur in these districts together with slow oxidation.

The early English makers made their acid by the distillation of "green vitriol" in earthen vessels, known as "long necks." Fifty or more of these were arranged in a reverberatory furnace and connected with glass receivers by means of luting.

Copperas works began in England at Hastly in 1748, and at Walker in 1797. After drying the copperas was distilled off by being laid in a brick oven and subjected to a strong heat; the gases, upon being condensed, formed an impure oil of vitriol. If one ton of copperas produced 1½ cwt. of acid it was considered a fair result. The price was two shillings (or say 50 cents) per pound. The prices ruling during 1895 have probably been considerably less than one-half cent per pound in wholesale quantities.

This process, owing to the expensive repairs made necessary by the intense heat required, was abandoned and the use of sulphur and nitre was adopted, the ore being burned in glass globes and the output concentrated in glass retorts or other vessels. This method was first introduced into England by Dr. Ward, who

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called his product "oil of vitriol made by the bell," and on account of its superior quality sold for the equivalent of from 37 to 62 cents per pound.

About the year 1746 leaden chambers were introduced by Dr. Roebuck and his partner, Samuel Garbett. Three years later these gentlemen made extensive experiments on the Eastern coast of Scotland, and the results of these experiments were published by Dr. Home, of Edinburgh, and led to the use of sulphuric acid for bleaching purposes. Sour milk had been used previously. A great demand was created for such acid for this purpose, and in 1790 England exported 2000 tons.

From this time great was the variety and size of leaden chambers, round, square, long, short, high and low, until the dimensions of the chambers which may be classed as representative of the best practice of to-day are from 80 to 100 feet long, 30 to 40 feet wide and 18 to 20 feet high. Departure from these sizes will be found in the best practice, but the sizes given above will be found in the great majority of cases.

In the early history of the manufacture of sulphuric acid 7 or 8 pounds of sulphur was mixed with one pound of saltpetre, and 300 cubic feet of chamber space was supposed to be required for one pound of this mixture. The sulphur and saltpetre mixture was burned upon hot plates, arranged upon a platform in the chamber a foot or so above the water, the chamber being filled to 6 or 8 inches in depth with water.

Mr. Park, in his "Chemical Essays," refers to the next improvement as a separate apartment in which the sulphur was burned. By this method one pound of sulphur gave $2\frac{3}{4}$ pounds of sulphuric acid of 1.848 specific gravity. This separate apartment or oven was round in form, made of fire bricks 4 to 5 feet diameter, having its floor 2 feet from the ground and an arched roof, the highest point being 2 feet from the floor. The front was supplied with a sheet iron door, and in this door a tin slide was arranged to admit the necessary air. The sulphurous gases were led off by a 12-inch iron pipe, extending from the roof of the oven and connecting with the chamber.

The next improvement was in making bricks of the sulphur paste, weighing about 20 pounds and dried on the top of the oven. With this improvement came the introduction of nitre in pots. The saltpetre was used in proportion of 1-10 of the sulphur, with sulphuric acid enough to make the proper decomposition, the residue from the pots being sulphate of soda or salt cake, or, more properly speaking, nitre cake. The gases entering the chamber

were cooled by water allowed to drop into it. Kestner, in 1828, introduced the use of steam in the place of water in the chamber. He also invented the "drop tube" for collecting the acid in the chamber for testing the strength.

Up to this time all gases passing uncondensed from the chambers were carried into the work chimney and thus diffused, to prevent as far as possible injury to vegetation.

The great change in the history of the manufacture of sulphuric acid was the substitution of pyrites for sulphur, and was made necessary in 1833, when the King of Naples granted to Messrs. Taix & Co., of Marseilles, a monopoly of the Cicilian sulphur trade, from which cause the price of crude sulphur advanced from $20 to $70 per ton.

Thomas Farmer, in 1839, was the first in England to use pyrites, although it had been used somewhat earlier in France. It is said that a Mr. Hill, of Deptford, had used sulphuret ore instead of sulphur in 1818 in an experimental way.

Spanish pyrites were used in 1856, Belgian in 1858 and Westphalian and Norwegian in 1861.

The first platinum retort appears to have been used in London in 1809. It weighed 423 ounces, and was very costly.

Previous to the introduction of platinum glass retorts were used for the concentration of sulphuric acid to oil of vitriol, but, as the expense caused by breakage was great, both in apparatus and in loss of acid, and as the suffocating vapors caused thereby were very annoying, the platinum retort, costing $10,000 and over, was used when the expense was not beyond the limit of the capital invested.

The manufacturers of platinum stills or other platinum apparatus are few, and, as the Russian Government holds a monopoly of the platinum mines (the only source of supply at present is found in the Ural Mountains), the prices for chemical apparatus made from this material are likely to continue at a high figure.

The latest improvement in platinum stills is referred to in a circular letter of W. C. Heracus, of Hanan, France, represented in New York by Charles Englehard, where the platinum surface exposed to the acid is gold-plated. The plating decreases the loss of platinum from 0.05 gramme in the case of pure platinum to 0.01 gramme in the case of gold-plated platinum. M. Heracus considers that the practical results obtained by gold-plating under his patent establish without further question the superiority of this method over all others.

The making of sulphuric acid from sulphur is a thing of the

past in this country, except where chemically pure acid is required. The system of manufacture, however, is similar to that described, minus the towers which are now universally used and will be described further on.

Iron pyrites are obtained from several sources in the United States. In fact, almost every state in the Union contains some pyrites. The principal sources from which our manufacturers draw their supply for acid making are Franklin County, Mass., Louisa and Prince William Counties, Va., and Paston County, N. C.

Since the year 1882 there have been mined in the United States 973,480 tons, the prices of which have declined from $6 per ton in 1882 to $3.24 per ton in 1895. Since 1889 the average yearly production has been about 100,000 tons, except in 1893, when it fell to 75,777 tons.

Little positive information can be obtained respecting the importation of pyrites for acid making previous to 1891, as all ores containing sulphur were classed as sulphurets. Since 1890 our Government has carefully separated these ores, so that it is now an easy matter to ascertain precisely what ores are used for our purpose. Since 1890 there have been received in the United States for acid making purposes 901,922 long tons, containing not more than 3½ per cent. of copper. Consequently it is allowed to enter duty free. The importations yearly and the prices for same have been as follows:

In 1891, 100,684 tons at $3.80 per ton of 2240 pounds.
In 1892, 152,359 tons at $3.86 per ton of 2240 pounds.
In 1893, 194,934 tons at $3.70 per ton of 2240 pounds.
In 1894, 163,546 tons at $3.62 per ton of 2240 pounds.
In 1895, 190,435 tons at $3.53 per ton of 2240 pounds.

The annual consumption of pyrites during these years was as follows:

	1891.	1892.	1893.	1894.	1895.
Domestic	106,536	109,788	75,777	105,940	99,549
Imported	100,648	152,359	194,934	163,546	190,435
Total	207,184	262,147	270,711	269,486	289,984

The supply from abroad is usually received from the Rio Tinto Company's mines in Spain, and contains, as an average, 48 per cent. sulphur, from 3 to 3½ per cent. copper, from 1 to 2 ounces of silver and about 1-10 of an ounce of gold, ¼ of 1 per cent. of arsenic, with traces of other metals, such as zinc and lead, the balance being iron ore, which, when separated, will test 67½ per cent. iron.

The Pennsylvania Salt Manufacturing Company, of Pennsylvania, imports the most, if not all, of the Rio Tinto pyrites, owing to their immense plants, by which they recover the silver, gold and copper as well as the iron from these pyrites. They not only import for their own direct consumption, but sell to other manufacturers of sulphuric acid, allowing them, for a consideration, to return the cinders after the sulphur has been burned off.

Formerly these pyrites were sent here in lumps of irregular size, and were crushed by the consumer; the crushing caused a considerable amount of "fines," which were difficult to burn in any quantity with the regular ore, as the fine material will clog

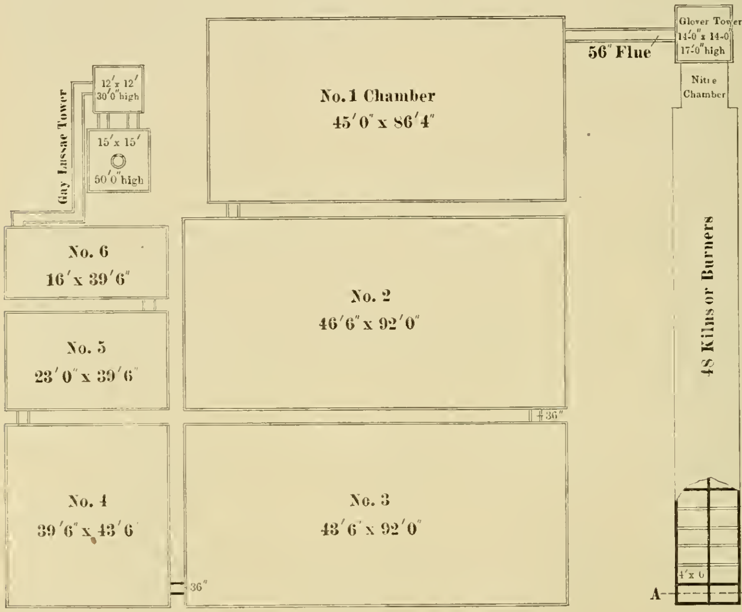


Fig. 1.
Arrangement of Chambers and Kilns.

the kiln and prevent a draught, causing the fires to burn low or die out entirely. Of late years it is the custom to purchase the ore already broken to size suitable for the kiln, and in this way there are little or no fines to be cared for.

The kilns, Figs. 1 and 2, in which the ore is charged regularly are made of brick, about 4 feet by 6 feet by 4 feet deep above the grate, and are set back to back in benches of twenty or thirty. The number of kilns will depend entirely upon circumstances. The numbers mentioned are usual in laying out new work. The writer has worked as many as 55 kilns in one set of chambers, the circumstances in that case having been such that it was preferable

to do so rather than attempt the separation of a large plant of old sulphur chambers.

These kilns are provided with full cast iron fronts covering the whole surface front of each kiln, and as the kilns are placed back to back there is an unbroken line of cast iron on both sides. The fronts are bound together by railroad iron buckstaves at the points where the fronts join each other. This makes a most effective binding, and the life of a kiln is in this way preserved for many years. Internally these kilns resemble a square box with a grate of $1\frac{1}{4}$-inch square wrought iron bars located above an ash or cinder pit 2 feet from the floor. The roof is arched directly over each kiln, and a second arch above this extending over both lines of kilns gives a suitable flue through which the sulphurous gases are conveyed to the Glover tower, Fig. 1. Each kiln is charged with the amount of pyrites it will successfully burn in a given time.

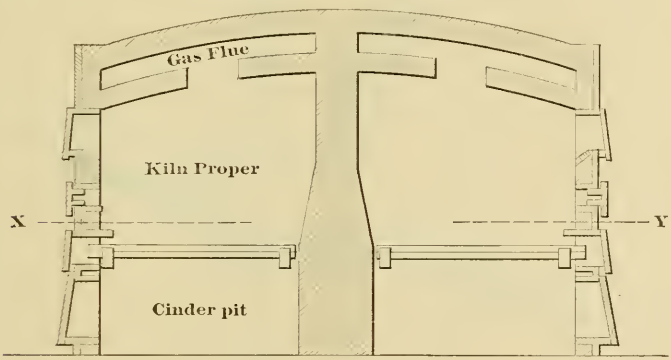


Fig. 2.
Section of Kiln Through A-B.

The kilns are charged in turn and as rapidly as possible, to prevent the admission of excessive air. The charging is done through a door in the fronts, arranged for the purpose, and the cinders are withdrawn from the pit before the charging is done. A crank, adjusted to the end of the grate bar, whereby each bar is rocked in succession, is the means for shaking the cinders into the pit. Sliding dampers in the pit doors allow of the proper regulation of draught, and a peep hole in the charging door allows of inspection of the interior of the kiln. In the center of front, below the charging door, is a circular hole, which is ordinarily filled with fire clay, but which, when required, serves for breaking up the ore in the kiln. This is seldom needed with even-sized pyrites, but when "fines" are used it is found very convenient. The gases evolved by the burning of the sulphur contained in the pyrites pass up through a hole in the roof arch into the flue above. At the

extreme end of the bench of kilns, and between them and the Glover tower, is arranged a nitre chamber, where the pots or vessels are arranged for distilling the nitrous gases which combine with the sulphurous and enter the tower on the way to the chamber. The combination of these gases in the presence of water causes a reaction, converting the sulphurous into sulphuric acid.

The Glover tower was invented by Mr. John Glover, of Wallsend, near New Castle, England, in 1859. It consists usually of a square structure made of heavy lead sheets, supported by a suitable framework about 10 feet square and 24 feet high. The lead walls are lined by acid-proof brick and filled with checker work of same material. This tower sits upon a foundation of brickwork usually built to the proper height and in a heavy lead saucer. The

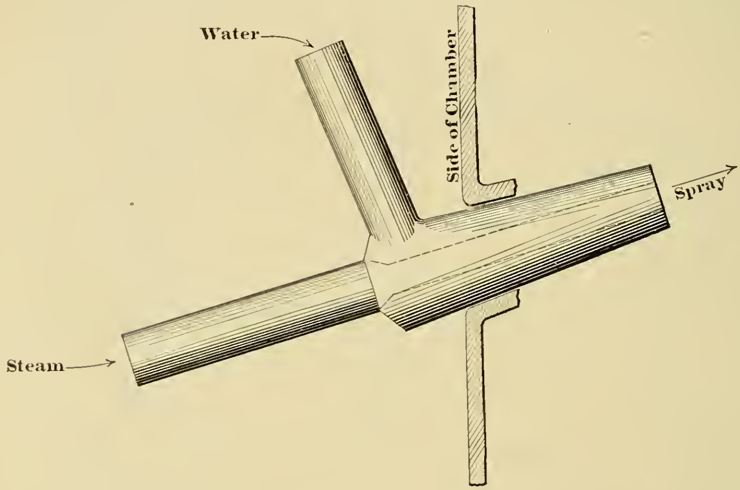


FIG. 3.
DR. SPRENGEL'S ATOMIZER.

gases, as they enter the bottom of the tower and ascend, are met by a shower of nitro-sulphuric acid, which is distributed from above by means of an ingenious arrangement of pipes from a distributing box. By this means the hot gases are cooled and the weak acid from the chambers is strengthened from 45° to 55-60° Beaumé, while the nitrous acid becomes denitrated. The gases not condensed in the tower pass over into the first chamber, together with the water evaporated from the weak acid and the nitrous gas. The arrangement of chambers is usually made to suit the convenience of location. In the writer's experience a variety of sizes and styles of arrangement have been used, varying in width from 34 to 44 feet, in length from 24 to 100 feet and in

height from 18 to 25 feet. The arrangement and size of chambers shown in Fig. 1 was designed and constructed by the writer in 1892, in connection with a complete plant for pyrites, and has given the greatest satisfaction of any in his experience. They have a capacity of 276,799 cubic feet, and are only 18 feet high.

Professor Lunge says, in his "Sulphuric Acid and Alkali," that all the work of a chamber is done midway between the top and bottom and first half, and this is borne out by the writer's experience. In order to effect the proper reaction the sulphurous and nitrous gases must be brought together in the presence of water, and water in the form of rain was first used but rendered the acid so weak, if enough water was used to produce the necessary condensation, that a large expense was involved in again concentrating the acid.

To obviate this trouble Kestner, as stated above, introduced a jet of steam, entering the chamber in such position as to assist the current forward to the next chamber. Dr. Sprengle, in 1876, introduced a patented form of spray nozzle, Fig. 3, in the sides of his chambers, about 40 feet apart, and with 20 pounds of steam was enabled to convert 80 pounds of water into a cloud-like mist at the rate of 750 pounds in twenty-four hours. By this method he claimed a large saving in fuel over that required for producing steam for the purpose. Professor Lunge gives as necessary for chamber service $1\frac{1}{2}$ pounds of steam per pound of sulphur burned. The writer's experience would place the figure at $1\frac{1}{3}$ pounds where the boiler is reasonably near the chambers and the pipes are properly protected from condensation.

While the work of oxidation is carried on principally in the first half of the chamber, and while practically the last half does no work, yet as soon as the gases are again drawn together in passing through the connecting pipe into the next chamber the work proceeds again for about one-half of the next chamber.

Lights of glass, arranged in either side of the chamber against the light from a window, show the working of such gases. The writer is of the opinion that a series of dishes, like dinner plates, for instance, piled across the chamber as a perforated partition about midway of the chamber, with the plates so piled as to leave reasonable interstices through which the gases could pass, meeting with a constant dripping of weak acid from the overflowing plates, would effect a better intermixture and cause a more rapid reaction, thus accomplishing a greater amount of work per cubic foot of chamber space.

The set of chambers above mentioned were supplied with 48 kilns, consuming the sulphur from 16⅔ tons of pyrites per diem. This is equivalent to 7⅔ tons of sulphur, and with this was used 345 pounds of nitrate of soda, equal to about 2¼ per cent. of the available sulphur contained in the pyrites,—*i.e.*, 46 per cent. of the 48½ per cent. originally contained. The reason for the extremely low percentage of nitre will be explained further on in connection with a second Gay Lussac tower.

Each chamber should be supplied with a thermometer and drip tubes. The temperature and the test of strength of the chamber acid should be recorded every hour.

As the remaining gases in the last chamber are and must be highly charged with nitrous gases, there would be a great loss of nitre as well as destruction to surrounding vegetation if these gases were allowed to escape. To accomplish the saving of this nitre Gay Lussac invented a denitrating tower, called, after him, the Gay Lussac tower. Although he made the invention in 1827, it was nearly forty years afterward before it was put into use, and no acid manufacturer of magnitude is to-day without it. This tower is similar in style to the Glover, but is filled with large pieces of hard-burned selected coke instead of chemical bricks or flints.

These towers are usually from 8 to 15 feet square, and from 30 to 40 feet in height. Professor Lunge says their cubical capacity should be about 1 per cent. of the chamber space, but our experience with the plant above mentioned shows that 2½ per cent is better, in the form of two towers.

The escaping gases pass up through the coke, where they meet with a fall of strong acid, distributed as in the Glover tower, and then escape to the air. By this means a saving of at least two-thirds of the nitre is made, and a large portion of chamber space is saved as well. The acid used in this tower becomes, of course, highly charged with nitre, and is used with chamber acid in cooling the Glover tower where the heat liberates the nitre, and it passes again to the chambers and is absorbed as before described.

In the plant above mentioned a second Gay Lussac tower, 15 feet square and 50 feet high, was used. The gases from the last chamber were sent through the first tower with a down-draft and entered the second tower at the bottom with an up-draft. This reduced the quantity of nitre to less than 2½ per cent. of the sulphur burned, with a chamber space of 19 cubic feet per pound of sulphur burned and a yield bordering on 300 per cent. of acid, 306 per cent. being the theoretical maximum. The writer does not claim the

idea of this second tower as original with him, as it had already been used, in one instance at least, in England.

The acid from chambers and towers is run into tanks lined with lead, and from them transferred to any part of the works desired by means of a receiver (called in England *an egg*) and by air pressure. Strong acid,—*i.e.*, oil of vitriol, can be stored or transported in plain wrought iron tanks, unlined, but the weak acid must have lined tanks. The weaker the acid the more rapid is the oxidation of the iron. The transportation of strong acid is almost entirely done in tank cars or boats of such shape and strength as to permit of their being discharged by air pressure.

The chamber acid from Spanish pyrites contains an amount of arsenic, in the form of yellow oxide, which must be removed before it goes to market, ordinarily, or to the platinum stills, and this is done by means of the Friburg tower. Here the acid, meeting a current of sulphuretted hydrogen made from the sulphide of iron, precipitates the yellow oxide. In this way the acid is freed from 85 per cent. of all the arsenic contained, and this percentage is sufficient for all ordinary trade purposes. Sulphuric acid made from arsenious ores is never used for medical purposes.

To concentrate the acid further to oil of vitriol it is necessary to use the still. In connection with the still is a series of pans of heavy lead, arranged in steps so that the acid fed into the first pan will overflow into the second, and so on until from the last it flows into the first or upper pan of the still. These pans are set on brickwork, over which are placed iron plates for the support of the pans. Under the lower pan, next the fire, it is necessary to have checkered arches of fire brick to prevent the action of excessive heat against the lead bottom. The fires from the stills furnish the heat for the pans.

The still is made either of platinum or of iron, or both. The iron still is of recent date, and answers very well for coarse acid; but for clear, fine acid the platinum still is required. The most acceptable style of platinum still in use to-day is in the form of a pan, not unlike a milk pan, about 36 inches in diameter and 6 inches deep, with a lead cover or hood arranged to receive a copious supply of cold water over its surface. Formerly three of these platinum pans were used as forming one still, but at present I believe only two are used. At least, where natural gas is used as fuel two were found sufficient. These stills are set like the pans, and overflow from one to the other.

The acid is fed into the first of the lead pans at from 48 to 50°

Beaumé, and in its course to the still becomes concentrated to about 60°, when it enters. It leaves the second still at 66°.

The iron still is used in a similar manner, except that only one iron still is used in place of two platinum stills.

The cinders containing the remaining sulphur, the difference between the original 48½ per cent. and the 46 per cent. which has been converted into sulphuric acid, is ground with salt to pass through a 20-mesh screen. The old chaser mill seems to answer this purpose better than any of more recent invention. The wear and tear is heavy, and the more cumbersome the mill the slower is the motion and the longer is its life. From the dry cinders, which are composed principally of the red oxide of iron, dust arises in clouds about the mill, and the manipulators resemble rather the red men of the forest than white laborers.

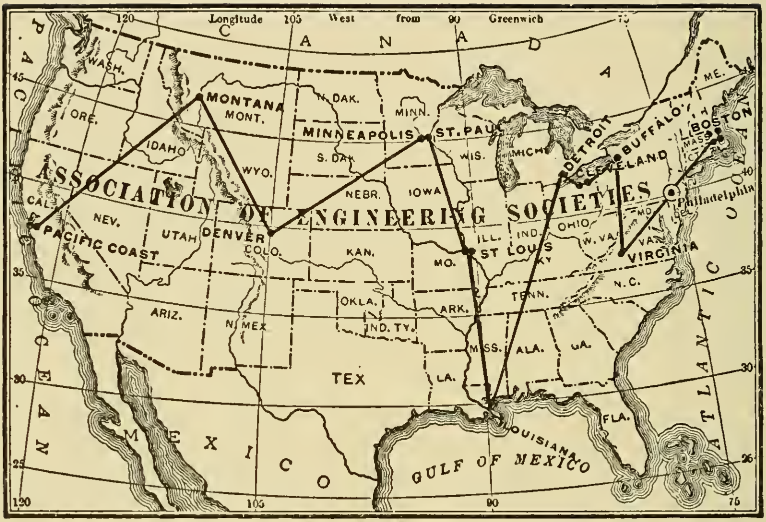
After grinding, the fine cinders are charged into muffle furnaces and roasted; and the remaining sulphur, in combination with the chlorine of the salt (with which the cinders are ground), is driven off in the form of gas and condensed in towers especially arranged for this purpose, giving a weak solution of hydrochloric acid which runs into storage vats. The roasted cinders are taken directly from the furnaces by iron wagons and dumped into leaching vats for the purpose of removing the silver, gold and copper. After filling the vats with roasted cinders the vats are flooded with the hydrochloric acid from the storage supply and allowed to stand until the liquor has taken the copper and precious metals in solution, when it is drawn into precipitating vats, where, by the "Claudet" process, the silver and gold are thrown down by iodine; after which the remaining liquor containing the copper solution is drawn into another vat in which scrap wrought iron is deposited and allowed to remain until the iron has gone into solution and the copper has taken its place in the form of "copper cement," which is dried and smelted in the ordinary manner. Where we had a solution of copper we now have a solution of iron, which, upon being concentrated and allowed to crystallize, gives sulphate of iron or copperas crystals. The silver precipitate or "mud," as it is called, is dried and put into Doré bars or sold as mud containing so many ounces of gold and silver as determined by analysis. The remaining iron in the leaching vats is withdrawn, allowed to drain on a table prepared for it and then dropped into railroad cars for transportation to market as iron ore. This method of extracting the metals from the pyrites cinders is called the wet or Henderson process. So far as the writer is aware, it is operated only by one establishment in this country. It is an exceedingly dirty process,

but very fascinating, as most chemical processes are. The wear and tear upon all parts are excessive. Iron cannot be used in connection with sulphuric acid in its weak state, lead being the only material, except glass and platinum, that can be used. In many parts of the work glass cannot be used, and platinum is expensive. Neither lead nor iron can be used in connection with hydrochloric acid. Either stone or wood must be used here.

Vats are usually made of wood, with double sides, ends and bottoms, and the space between say 1½ to 2 inches is filled with pitch cement and the whole interior painted with hot hard pitch. All joints where stones are used are made of rubber protected by pitch, and their interior surfaces are painted with the same material. All woodwork is put together with tree nails and bound on the outside with iron rods and painted with pitch. The average life of such work scarcely exceeds eight years.

A *résumé* of the foregoing shows that out of the Spanish pyrites all the sulphur is converted into sulphuric acid (or hydrochloric acid). The copper, silver and gold are saved to within 2 to 3 per cent. of the total contained, and a large portion of the iodine used is recovered. The scrap iron for obtaining the copper is returned in the form of copperas. While the original iron ore contained in the pyrites is saved and used by blast furnaces, this ore, as stated above, is of 67 per cent. iron, and known as "Blue Billy" or "purple ore." It can be ground and used successfully as an iron paint.

For many points in the early history of the manufacture of sulphuric acid the writer is indebted to Professor Lunge's "Sulphuric Acid and Alkali," and Mr. Charles T. Kingzett's "History, etc., of the Alkali Trade," and for statistics to Mr. E. H. Parker's report for 1895 to the Department of the Interior.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THE EVOLUTION OF STRUCTURAL DESIGN.

BY F. T. LLEWELLYN, MEMBER OF THE LOUISIANA ENGINEERING SOCIETY.

[Read before the Society, September 19, 1898.*]

IT is the purpose of this paper to show how the development of Structural Design is due rather to varying and improved conditions governing cost and availability of material than to more perfect knowledge of the theories of mechanical statics. The writer does not intend to treat of ornamental design, with classification and details of the various forms and mouldings adopted under historic régimes, but will endeavor to restrict himself almost entirely to that part of design (especially frame-design) which by the use of the most effective and economical materials overcomes such natural forces as those exerted by dead and live loads, wind pressure and the effect of heat and cold, and he feels that it is not unsuitable for him to take up such a subject, on account of his double duties in both contracting and engineering; in combining which the truth of his initial statement is being frequently evidenced. The principal authorities consulted have been Ferguson's History of Architecture, Cooper's American Railroad Bridges and Weale's book on Tubular Bridges.

Going back to the earliest civilizations, we find that their roofs and arches show most plainly the action of the above-stated principle. In Egypt the most primitive structures had each opening spanned by a single stone, in many cases of great size.

*Manuscript received October 24, 1898.—Secretary, Ass'n of Eng. Socs.

Their temples consequently show the ruins of many interior supports; but mystery and gloom being so large a part of their religion, the multitude of heavy stone columns covered with hieroglyphics was congenial rather than otherwise. There is no evidence that their old temples were roofed in any other way than by single stones, although structures of later times show signs of arched coverings.

The Greeks and Romans often used the same method, and have left one example, the Mausoleum of Theodoric at Ravenna, which has a domed roof formed of a single stone nearly 35 feet in diameter,—a size which makes us think meanly of this century's masonry. The Greeks also used wooden beams as roof supports, which have almost entirely perished, but their construction was luckily copied in the stone friezes which remain to-day, wherein the ends of the rafters with all the necessary cleats and nails are reproduced in the carved masonry.

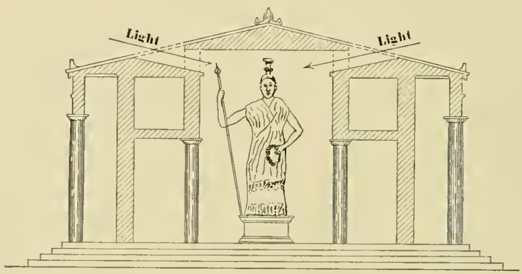


FIG. 1.

Their temples seem to indicate a very ingenious mode of lighting the interior without impairing the harmony of the exterior, which might teach a lesson to some of the builders of our older office blocks.

The inside of a Greek temple contained nothing but a statue of the patron god, upon which it was very desirable to cast a good light, the roof being arranged as in Fig. 1.

To the Romans we owe the elaboration of the arch,—*i.e.*, the radiating arch,—for there was among the Hindus a very different kind of arch in use. Not very many of the oldest Roman buildings were covered in this way, but it was used extensively in tombs, drains and treasuries. It is easy to see how the arch came to take the place of single huge stones, such as were employed by the Egyptians. The only way in which such heavy pieces could be handled, without the use of machinery, was by working hundreds of people, who had to spend their lives in lifting. Egypt had thou-

sands of such able-bodied and ambitionless slaves, while Rome in the earliest times owned very few slaves, and later they were so weak and effeminate that such tasks would have been impossible. The rocks themselves also were more readily used in smaller pieces. The evolution of the arch was like this: First, a single stone beam was used to span an opening, then, when the length became too great, two stones were inclined together, and soon a third was added, which we now call the Keystone, and with more skilled masonry work the number of stones was increased as shown in our own arches. (See Figs. 2-5.)

In India there are arched roofs built on an entirely different principle. Such examples as have just been described cause an outward thrust at the spring, more or less great according to the span and versed sine, which has to be overcome by the dead weight

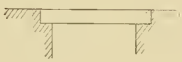


FIG. 2.

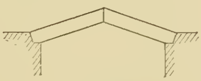


FIG. 3.

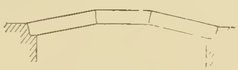


FIG. 4.

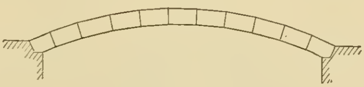


FIG. 5.

on each side. The joints all pointing to a common center, they are called radiating arches.

This outward thrust was altogether distasteful to the Hindus (they have a proverb that "an arch never sleeps"), and so they built what is called the horizontal arch, which in section looks like a number of cantilever brackets, but is not so.

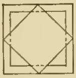


FIG. 6.

They first employed the simplest method of covering a space with a single stone, thus: but for the ordinary use that practically limited their openings to about 4 feet square; and so they filled the corners with four triangular stones, resting the single stone upon them; and so covering a space of about 6 feet square without using a stone bigger across than 4 feet. (Fig. 6.)

With an increasing number of stones, extra supports were found necessary round the sides, but leaving a clear space in the center of sometimes 40 feet square, which would look like Figs. 8 and 9.

Such an arrangement will of course bring quite a bending moment on the lower course of stone, but there will be no outward thrust.

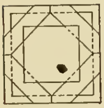


Fig. 7.

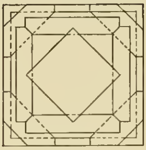


Fig. 8.

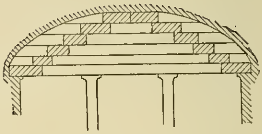


Fig. 9.

The Chinese have to use an entirely different material, which abounds in that country,—viz, a species of small pine which has the peculiarity of being soft and spongy inside, while the outer rims of wood just under the bark retain their strength and hardness. It is thus practically a wooden cylinder, good for direct compression and bending if left whole; but if sawed into planks, or "sticks" as we say, to form any kind of a trussed framing, would fall to pieces; like a built section of plates and angles with the

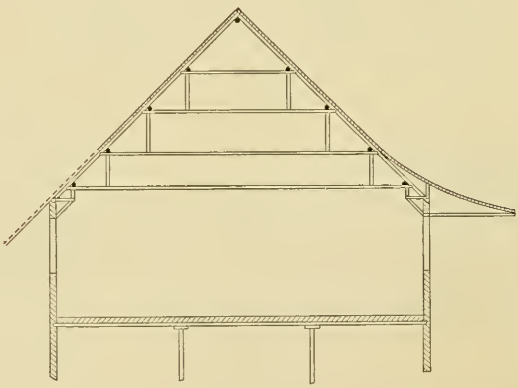


Fig. 10.

rivets left out. Therefore they make their upright supports of these small trunks, bracing them along the sides of the building with "sway knee-braces" of the same material, only smaller growth, and arrange their framing by means of a series of horizontal beams, each having its ends supported on that below by a short vertical strut of a sounder but rarer kind of wood. (Fig. 10.)

It is interesting by the way to notice how the requirements of

the Chinese climate are met by the peculiar outline of their roofs, which are concave. This is *not* copied from the tents of the wandering Tartars, which in fact were always domical, but they are so shaped for two reasons. During their rainy season such large quantities of water have to be carried off the roof that a low pitch would cause leaks, and therefore the part over the house must be steep. At another season of the year it is absolutely necessary that some shade be provided over the windows from the fierce, glaring sunshine. Now, if the roof were to run out over the windows far enough to furnish ample shade from the sun, it would come down so low as to also keep out the light and air (see dotted line at left of Fig. 10), and, consequently, John Chinaman curves up his eaves outside the walls, where a perfectly water-tight covering is not so necessary, thus forming the peculiar shaped roof with which we are familiar.

There is a method of roofing which should be mentioned before going into the growth of trussed structures,—viz, groining, which is essentially a combination of arches, meeting together, the lines of greatest pressure being marked by ribs, which in later ex-

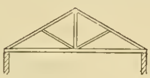


FIG. 11.

FIG. 12.

amples were often highly ornamented. Chapter houses of the old world cathedrals were generally covered in this way.

With the advancement of civilization there was a demand for more buildings, which were required to be erected in less time than had previously been the case, and a change from the old arch practice was necessary. To meet the new circumstances, the trussed roof was evolved, like the arch, from very simple elements. The commonest way of spanning openings up to about 12 feet had been by means of a single wooden beam. Wider spans suggested two beams sloping together; but instead of resisting the outward thrust so caused by means of buttresses outside the building, a horizontal tie-beam was thrown across, holding the two feet of the rafters together. (Fig. 12.)

When still greater spans were required the middle of each rafter was supported by means of struts, sloping in towards the bottom of a vertical post which ran from the apex to the middle of the tie-beam, so forming the well-known king-post truss. (Fig. 11.)

Further developments brought forth the queen-post truss, and others with more members to suit the span.

The larger use of timber framing followed the introduction of saw-mills. The earliest methods of cutting timber had been by wedge-splitting, which although it injured the fiber less was very slow and expensive. The Greeks invented the hand-saw, modeled either on a serpent's tongue or the backbone of a fish, and there is a literary allusion in fifth century writings that suggests crude saw-mills then; but not until the fifteenth century do we find reliable indications of wind saw-mills in Germany; and in England early in the seventeenth century, accompanied, as usual with all mechanical improvements, by the greatest opposition on the part of the workmen. Simultaneously we find the elaborately framed roofs of the perpendicular period.

There is a peculiar sort of roof-truss common in many old churches which made use of the hammer-beam. Essentially this truss is framed by merely putting a pair of brackets in the walls, and resting the truss on their ends. (Fig. 17.)

These were profusely carved and ornamented. There is a good example of the hammer-beam roof in the west wing of D. H. Holmes' store on Canal street in New Orleans.

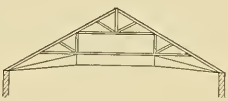


FIG. 13.

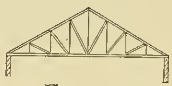


FIG. 14.

But all these older forms of trusses were made almost entirely of timber; with new methods of producing iron, and consequent diminution in its price, we see many changes. Keeping the same arrangement of members, those in tension were gradually replaced with iron; first the king-post (called the king-bolt when made of iron), and later the tie-beam, gave way to the iron horizontal tie-rod. It is curious to notice how closely the carpenters of those days kept to the memory of old timber trusses, and what abortions were often the result of its union with iron. Here is a roof-truss stretching across a hundred-foot span drill hall, in which we see the king-post at the top, lower down the queen-post, and some iron rods thrown in at the bottom. (Fig. 13.)

Perhaps the best type of this combination truss is the Princess, in which it will be noticed that the ties, which are iron, have a minimum length, an arrangement due to a desire to use as little as possible of a comparatively expensive material. (Fig. 14.)

The well-known Howe truss exhibits similar economy.

When the manufacture of cast iron became more reliable and better understood the compression members or struts were made

thereof; but as one of its properties is a great loss of strength when in long unbraced lengths, another change in the arrangement of members was required, which resulted in various forms of the Fink truss, which has short struts and long ties. (Fig. 15.)

This truss can be well used for bridge spans by turning down, and they tell how its introducer, an army officer in the Civil War, made a novel use of its properties to fool the enemy, who had been accustomed to bridges with two parallel chords. The Fink truss

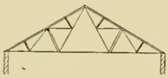


FIG. 15.

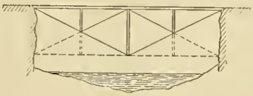


FIG. 16.

can be quickly built in an emergency, and when it was necessary to throw a bridge across water he used this type, but added superfluous members in the shape of a dummy bottom chord. (Fig. 16.)

The opposing forces, wishing to destroy the bridge, and supposing it to depend on the bottom chords, shot them away, when of course the essential members remaining intact, she stood solid, presumably to their great amazement.

FIG. 17.

This Fink truss is now well adapted to shipment, being riveted up at the shops in two (or for large spans, four) sections, which can be easily suited to railroad car capacities, and assembled in the field; whereas the older forms for larger trusses had either to be shipped with each member separate, or they were too high for transportation.

The struts in Fink trusses generally consisted of hollow cast iron tubes, attaching to special fittings at each end, and often orna-

mented at the middle with a shell casting. Such a connection is all right for a member always in compression; but when it became desirable to replace the building walls also with iron, wind strains often induced tension in some of these struts, for which the cast iron forms used were altogether unsuited. Then came the invention and improvement of new processes for making rolled sections, careful tests of properties and new tools, which combined to give sections strong both in compression and tension, of which the best modern roof frames are constructed. As a further example of the dependence upon shop work for our best practice in construction, it may be noted that until quite recently it was usual to make some allowance in the length of members, to be adjusted during erection with wedges, etc., a device which would throw out any careful and exact calculations.

The way in which iron and steel have entered into our roof construction is capable of much further illustration, having many points in common with modern bridge construction, as compared with older methods. In the first twenty pages of Theodore Cooper's book on American Railroad Bridges he shows how

FIG. 18.

wooden bridges were gradually improved with, and then replaced by, iron in its various forms, and there may be found many examples of this reconstruction period, which will also apply to large span roofs. From Mr. Cooper's very quaint list of old-time structures, and such other sources as have been available, the following may be of interest:

The first iron bridge in England was built about 150 years ago near Coalbrookdale over the Severn. It is a 100-foot span arch of cast iron. The 250-foot cast iron arch spans of the Southwark Bridge, London, built about 1810, are still in use. Cast iron was also used up to the middle of this century for railroad bridges, up to 40-foot spans, a girder section of this kind being used, but its liability to crack under impact and to fail in the tension flange rendered these unsatisfactory. (Fig. 18.) The first wrought iron to be rolled was by Cort, of Southampton, England, under patents of 1783, and during the first half of this century such wrought (or "malleable," as it was called) iron as was used, either for reinforcing tension flanges of cast iron, or later alone, had to be punched, beveled, bent, etc., either by hand or by means of a lever-fly, which machine consisted of a large weight acting at the end of a lever to

work the metal, something like a garrote. But in 1846-9 the hydrostatic press and steam riveter were introduced, whereby all shop work could be performed more economically and accurately, and access to these tools caused Robert Stephenson, William Fairbairn and Eaton Hodgkinson to decide on the use of wrought iron for the famous Britannia Bridge across Menai Straits. This structure has never been surpassed in many respects, and a few data may be of interest. It is called a tubular bridge, and is in theory constructed like an immense box girder, the train passing through the box. The top and bottom flanges consist of cells built up of plates, angles and tees, each cell being large enough for a workman to get inside to rivet up. In section this girder looks like Fig. 20.

Each tube is 472 feet long, two being placed side by side for the two railroad tracks, and the bridge consists of four spans resting on five masonry piers, 100 feet above water line. Each tube weighed over 1600 tons, and on account of the constant passage of vessels had to be constructed on trestling 100 feet high, on

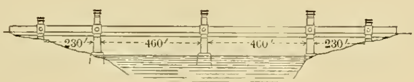


Fig. 19.

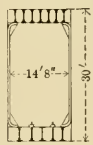


Fig. 20.

pontoons, and floated into place complete, the exactly correct elevation being secured by pumping water in or out of the pontoons. The first tube took two hours to get into place from the time it left its moorings. And all this in 1850, and over open sea water! (Fig. 19.)

But even these methods of working the material were comparatively crude and expensive (wrought iron being then worth nine cents per pound), and prevented its general use; and in the popularizing of iron for structural purposes we have to look to three causes, two of them entirely American,—viz, Eads' wonderful bridge at St. Louis, and the development of pneumatic tools. The other, Bessemer's process of converting pig iron directly into steel, is an English invention, but its fullest developments have occurred in this country.

Taking up the Eads' bridge first, 1868-74, one must note that the mills then rolled very few of what are now called "standard sections," each manufacturer turning out such shapes as appeared right in his own eyes. A glance at the catalogues of ten years ago shows that even then much of this isolation had not disap-

peared. It was necessary then for Mr. Eads not only to develop his general design, proportion the sizes of members and provide for his revolutionizing method of erection by the cantilever process, but, being unable to find the sections required on the market, he had also to design them, and indeed very largely the machinery for rolling them. After much discouragement he succeeded, and immediately there appeared the beginnings of that tendency to "standardize" which in its fullest developments enables one to telegraph to the shops an order for quite complicated structures in half a dozen lines, and know exactly the detail dimensions and arrangement of the material that will be shipped.

The next step was the Bessemer converter, which has enabled structural steel to be marketed at a price one-third of that obtaining for iron twenty years ago, and this for a material stronger by 25 per cent. Until quite recently Bessemer steel has been used more for buildings than for bridges, for a reason to be mentioned later; but its use in conjunction with hollow tile has made possible the twenty-six story buildings of the present time, combining cheapness, lightness and strength with the more convenient arrangement of interiors thereby made possible. Having then this material within reach, our engineers have developed its use along new lines to an unprecedented extent. The concentration of the loads in a building on the columns only has caused new departures in the way of foundations for soft localities, and has enabled the loftiest structures to be built right up against old and small ones, with minimum party wall damage and litigation.

But for a long time Bessemer steel has been debarred from railroad and other important bridges, etc., on account of the supposedly injurious effects of *punching* in disturbing the metal surrounding a hole. Engineers have specified that if used it should be drilled instead of punched, or reamed out, which has made its shop cost almost prohibitory. Just what the extent of this injury is has been a debated question; but the tool manufacturers have happily taken it out of the domain of practical questions by the series of pneumatic tools that have recently been put on the market, and by whose use holes can be sub-punched and reamed many at a time at a very low cost. These tools are also successfully used for shop and field riveting, beveling, caulking and many other purposes, insuring the highest class of workmanship. The effect of these improvements has been not only to give us better structures, but has caused a marked change in the practice of designing bridge spans. A few years ago a 100-foot span was always built on the pin-connected type. Now, such a span is preferably riveted

plate girders or lattice trusses, on account of rigidity; and with the larger use of the latter, theoretical points have arisen and been largely settled concerning the action of stresses in same and proper connections.

It may be of interest here to briefly compare American with what has been European (especially English) practice in bridge construction. In this country the entire working of the material is done at the shops, from details and templates very accurately prepared; and it often happens that half the members in a structure come from one place, and the balance 1000 miles away, and are never brought together until assembled in place at the site. So happily has this work been systematized, and so carefully are the working drawings checked and followed, that discrepancies need not be feared. In English shops the practice has been very largely to *cut and fit*, using fewer drawings and placing more de-

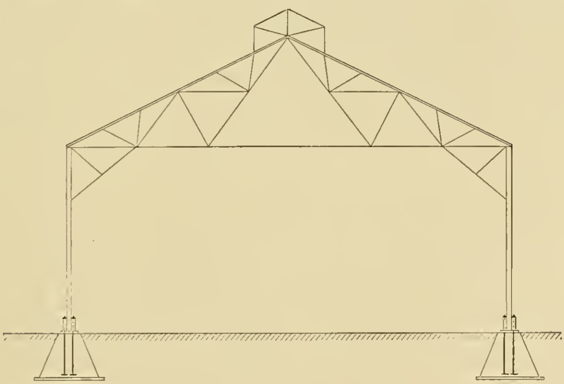


FIG. 21.

pendence on the workmen. During the construction of the Britannia Bridge, about 1850, and the Forth Bridge, as late as 1890, large shops were temporarily erected at the sites, where the various pieces were measured for and then worked piecemeal. In the case of a large bridge over the Indus in Hindustan, the London builder even went so far, in his fear of misfits, as to erect the entire structure in his yards before shipment, and then take down before sending away. An enormous expense! This comparison may throw a little light on the causes of America's recent success in competing for this class of work; for we secured the large Hawkesberry Bridge, Australia, against the world (the metal being manufactured and completely worked ready for erection in Pennsylvania), and we have lately been low bidders on several structures in Europe itself.

As an example of the effect of local conditions in bringing out well-known but little-used theory, the writer may briefly refer to a

point in his own New Orleans practice, in connection with light steel buildings, consisting of bents composed of two columns supporting clear-span trusses, with purlins and girts between, and lateral bracing. (Fig. 21.)

Such a bent is figured to resist the force of side winds by the action of the knee-braces, whose kick is withstood by the moment of resistance of the columns, and whose stresses are transmitted through the truss-members to the opposite side. The columns in other localities are customarily provided with small steel shoe plates, and short anchor bolts, say 15 inches long, and the lower end considered *hinged.* Now it is well known that a beam *fixed* at one end is much stiffer than if merely supported there; and a short consideration of our local conditions showed the possibility of this increased stability and economy. All our ground here is very soft and damp, and will carry only one-fourth the load that sounder soils elsewhere do. This means that the foundations for columns have to be unusually large and deep. Why could not these masses of masonry be utilized for "fixing" the feet of columns, thereby producing a point of contraflexure that would reduce the leverage of the wind-kick, and enable the sections of columns, knees and truss-members to be made lighter, and with increased stability?

The large anchor bolts (av. 2″ upset x 7.0″) and stiffener angles do not weigh as much as the saving in framing above, and the cast base-plates required for this construction are just what is needed to prevent the dampness rising to attack and rust the more susceptible steel above. This fixing the column bases also facilitates erection, and tends to prevent accidents during raising.

In conclusion attention should be called to the fact that since our earliest history there has been but little modification of the theories that govern a frame structure; and necessarily so, for they are simple and unchangeable. I count but three, and two of them were stated by Euclid and Archimedes over 2000 years ago so clearly that we still use their writings as text-books in our schools. These are:

1. The Triangle of Forces.
2. The Lever.
3. Ut Tensio Sic Vis.

If one can clearly follow out the workings of the first two, he can compute the stresses induced in the most complicated framing ever designed. A thorough understanding of the last is all that is necessary to properly proportion the various members to safely resist those stresses. The evolution of structural design has come about *not* so much from a deep searching into the abstruse mys-

teries of pure mathematics, as by the continuous and intelligent endeavor to meet the requirements of the thing in hand in countries widely remote, under changing conditions, and with materials of varying capacities.

We have seen how structures of such different types have been used, and why: the single huge stones in Egypt, because their shop or rather their field practice was to handle great masses; the stair-truss in China, due to the peculiarities of the timber there; the horizontal arch among the Hindus, because the radiating arch "never sleeps," and that would not suit a Hindu; the groined vault and heavily timbered roofs of Gothic church builders, those being the forms which would most readily adapt themselves to the interior decorative effects of which they were so fond, and which could then be cheaply sawed; and finally the steel roofs and bridges of our own time, which are the outcome of the experience and labor of our forefathers, the inventive genius of our ironmasters and the increased capabilities of our mechanical tools, combined with the demand for such mammoth structures as we see going up all around us.

THE MACHINERY OF VESSELS ON THE GREAT LAKES AND A SYNOPSIS OF RULES COMPILED BY THE GREAT LAKES REGISTER.

By John N. Coffin, Member of the Civil Engineers' Club of Cleveland.

[Read before the Club, September 13, 1898.*]

In 1896 the *Great Lakes Register* was organized to compile a complete classified register of all the shipping on the Great Lakes, the classification to be the basis for insurance rates for use by the marine underwriters.

The work of inspection and classification was started and carried on for some time under the sole direction of Captain F. D. Herriman, but later it was determined that a more thorough inspection of the machinery of the vessels than was at that time being made was necessary, and in February, 1897, our fellow-member, Mr. Walter Miller, was asked to take charge of this part of the work; and what is known as the Machinery Department of the Register was organized. As Mr. Miller has had full charge of this work I had hoped that he might be prevailed upon to favor us with a paper on the results, but he has requested that I write on the subject; and, as I have been connected with him throughout the entire work, I will, to the best of my ability, outline some of the results which have been developed.

As the classification of the vessels on the lakes was for the use of a combination of marine insurance underwriters, representing a number of insurance companies, it was necessary that the inspection and classified ratings should be made by absolutely impartial surveyors, so that each vessel should be given an unbiased and fair classification.

In the organization of this department our first idea was to secure a corps of thoroughly competent and impartial surveyors, and to formulate for their use rules which would insure thorough inspection and comprehensive reports, which would give us a complete description of all the machinery, both as to sizes of parts and as to their condition.

I will hand you one of our blank reports of survey, which, if you will examine it, will give you a much better idea of the completeness of the survey than I could by description. In addition

*Manuscript received October 15, 1898.—Secretary, Ass'n of Eng. Socs.

to the blank spaces for sizes and dimensions of parts of the machinery, you will note that blanks with headings for the description of the condition of the several principal parts of the machinery are shown. We have required answers in each of these blank spaces, thus assuring us that the surveyor had seen the parts and examined them, whether they were in perfect condition or not. The work of our surveyors has been very satisfactory, and their care in following out the minutest details has been of great assistance to us in our work of properly classifying the machinery. In this connection I would say that in several cases where vessels had been inspected by one surveyor they were afterward re-surveyed by another, thus giving us an opportunity of comparing their work; and in every such case this comparison has been very satisfactory.

Of more than 1300 vessels surveyed, we have found 1150 to be screw propellers and a trifle over 50 to be paddle, or side-wheel, propellers, the balance being schooners or tow barges equipped with boilers and steam pumps or with hoisting or steering machinery.

Of those fitted with screw propellers we have found that 960 had solid cast wheels, 6 of them being of bronze, 8 of steel and 946 of cast iron. One hundred and eighty-five had sectional wheels, one of them being bronze, 6 steel and 178 cast iron. Of the entire number, 1060 of these propeller wheels were fitted on the tail shafts with straight bore and key, while only 74 were fitted on a taper end with feather and nut, the latter arrangement being more modern practice and considered by most engineers to-day to be the preferable way of fitting propellers to the shafts.

Of the paddle wheels, we found 23 to be fitted with feathering floats and 29 to have solid floats.

Number of Vessels Built in each Decade.

Engines.	1860 to 1869.	1870 to 1879.	1880 to 1889.	1890 to 1898.
H. P. non-condensing	40	93	185	93
" condensing	6	10	5	4
Steeple compound	22	62	89	39
F. & A. "	5	12	154	99
Triple expansion	..	..	67	147
Quadruple "	..	..	1	6
Walking beam	8	10	8	7
Inclined and horizontal	1	2	7	9
Boilers.				
Fire box	18	97	392	224
Scotch	1	8	193	348
Water tube	..	1	...	35

Pressures.				
Below 50 lbs.	5	3	2	3
Above 50 lbs. and " 75 "	4	19	23	10
" 75 " " " 100 "	5	59	122	29
" 100 " " " 125 "	1	25	318	173
" 125 " " " 150 "	..	3	52	184
" 150 " " " 175 "	..	1	70	161
" 175 " " " 200 "	..	..	..	19
" 200 " " " 225 "	..	1	1	12
225 lbs.	..	..	..	2
250 "	..	..	..	12
265 "	..	..	..	2
300 "	..	..	..	1

Number of Vessels in each Rating, by Decades.

Ratings.	1860 to 1869.	1870 to 1879.	1880 to 1889.	1890 to 1898.
50	3	4	4	2
55	2	3	2	4
60	5	11	11	2
65	4	10	16	7
70	2	18	27	6
75	2	19	58	23
80	1	25	78	40
85	1	18	88	54
90	..	9	138	119
95	..	5	87	124
100	..	..	62	223

Referring to the table of engines, you will note some very interesting data relative to the advent and growth of the different types of engines.

For instance, you will note that the high pressure non-condensing engine, our earlier type, held the supremacy in numbers up to the end of the decade 1880 to 1890. This is accounted for in some degree by the fact that during the latter part of this period many small boats and tugs were built. The high pressure condensing engine cuts very little figure on the lakes, there being a total of only 25 in existence there.

The steeple compound engine had an early start, 22 of them now in existence having been built earlier than 1870, 62 during the next ten years and 89 during the period from 1880 to 1890. This type then gave place to the advent of the fore-and-aft compound and triple-expansion types.

Of the fore-and-aft compound type we have five engines built earlier than 1870. This type also reached the height of its popularity during the years 1880 to 1890, and then gave way rapidly to the triple-expansion engine, which makes its first appearance during this term with 67 examples, and which has held its supremacy with 147 engines built since 1890.

The first quadruple-expansion engine was built in 1889.

Since that date there have been 6 vessels equipped with this type of engine, and there are several of this type now under construction.

Of the paddle-wheel boats, you will note that 33 engines are of the common and well-known walking-beam type, while 19 are either horizontal or inclined engines.

It is also interesting to note the changes which have taken place in the types of boilers. The marine fire-box boiler is the most common type, though it has lost its prestige, the Scotch boiler having rapidly displaced it of late years. Seven hundred and thirty-one boilers of this type are in use to-day, 18 of them having been built earlier than 1870, 97 of them between 1870 and 1880, 392 between 1880 and 1890 and only 224 since 1890.

The Scotch type of boiler has one example built earlier than 1870, 8 between that and 1880, 193 between 1880 and 1890 and 348 built since 1890, a very rapid increase during the last seven years.

The marine water-tube boiler is of more recent date, only one having been built earlier than 1880. There are none of this type now on the lakes built between 1880 and 1890, but there are 35 vessels, built since 1890, equipped with this type of boiler; and there are several vessels now under construction which are to be equipped with this type of boiler, and it is the opinion of many engineers that the water-tube boiler is the coming boiler for marine use.

It is also interesting to note the gradual increase in pressures in boilers built during these several periods.

In those built earlier than 1870 100 pounds per square inch is the highest pressure, and there is only one boiler of this period carrying as high as 100 pounds and only one carrying 90 pounds, most of the boilers built during this period carrying pressures from 40 to 55 pounds.

Most of the boilers built between 1870 and 1880 carry either 80, 90 or 100 pounds pressure, though there are a few, built during this period, carrying considerable higher pressure and one carrying as high as 200 pounds.

During the period of 1880 to 1890 276 boilers were built which carry 100 pounds pressure or less, and 318 which carry more than 100 pounds; but there is only one boiler built during this period carrying as high as 200 pounds, 29 carrying 160 pounds, 39 carrying 150 pounds and the balance ranging from that down to 100 pounds pressure.

Since 1890 the tendency has been to a considerable increase of pressure. Only 91 of the boilers built during this period carry as low as 100 pounds, while 517 carry pressures higher than 100

pounds. Of this number 75 carry 120 pounds, 82 carry 125 pounds, 45 carry 150 pounds, 83 carry 160 pounds, and from that on up to 300 pounds, there being one boiler carrying this highest pressure, 2 boilers carrying 265 pounds pressure and 12 boilers carrying 250 pounds pressure.

In our survey of boilers it was not deemed necessary to make hydrostatic tests, as every boiler has to pass a Government inspection and test each year before the vessel is licensed to sail. Our survey has, therefore, been only for condition and to ascertain the care that the boilers receive. In this connection we have found 295 boilers to be patched inside, and 264 to have patches on the outside. Eighty-two boilers are shown to be poorly fastened to the hulls of the vessels; 139 boilers are without stop valves between them and the throttle valves; there are 191 cases where the slip-joints in the main steam pipes are not protected with safety guard bolts; there are 134 cases where there are no cocks between the feed check valves and the boilers, and there are 165 cases where the feed check valves are only common pipe checks.

Referring back to the subject of engines, it was rather surprising to find the lack of uniformity of proportion of parts of these machines. There seem to have been no hard and fast rules for the construction of engines on the lakes, and each builder has followed his own ideas to a greater or less degree in the proportion of the several parts of the engines he built, as well as in its special design. In the item of crank shafts we have found that about 400 were of the solid forged type, 17 of these being of steel and 383 of wrought iron. Seven hundred and eighty were built-up shafts, of which 23 were of interchangeable sections, 13 of them being of steel and the remainder of wrought iron. Of the total number, 354 were found to be light in section, according to the Lloyds's rules for determining the size of crank shafts.

We also found 106 cases where the intermediate shafts were light of section, and 387 cases where the propeller shafts were light of section, by these same rules; and we found 48 cases where the shaft couplings were reinforced, either on account of breakages or because of developed weakness.

There were also found 296 cases where the thrust bearings were insufficient to properly relieve the crank shafts from fore-and-aft strains. A perhaps more serious defect, from the insurer's standpoint, was found in the light cross-head connections, 446 cases occurring where cross-head keys were too light and 54 cases where the nuts fastening piston rods into cross-heads were small. This is a serious defect, and several recent accidents have occurred from

light construction in these parts. A point which seems to have been very sparingly covered by authorities on engine design, and yet which seems one of vital importance to us, is the bolting of cylinders to columns, of columns to bed plates and of bed plates to seatings in marine engines. The strain to which each of these parts is subjected being a direct strain, the necessary strength of these parts is easily found by computation based on the steam pressure and the size of cylinders. In these parts we have found 340 cases where the cylinders were too lightly fastened to the columns, 68 cases where the columns were insufficiently secured to the bed plates and 64 cases where the bed plates were not sufficiently bolted to their seatings.

We have also found several cases where the fastening at the ends of connecting rods is too light for safety.

In most of the cases where light cross-head connections and insufficient bolting of cylinders to columns, columns to bed plate and bed plate to seatings were found, the condition has occurred through the replacing of old, worn-out boilers by new boilers of higher pressure without increasing the parts of the engines; but we have also found several cases of recent construction where these parts were originally made entirely too light for safety.

The use of relief valves on steam cylinders has been appreciated only since the compound engines and higher steam pressures have become common, but it has become a matter of vital consideration. We have found over 650 cases where the cylinders were not so safeguarded. Many of these, however, were non-condensing engines, carrying only moderate steam pressures, but we have found 58 cases where cylinders were cracked and patched and in most of which the damage might have been avoided had there been proper reliefs.

In the cast iron parts of engines, such as bed plates, columns and channel plates, the builders on the lakes have not been sparing in the use of metal, though we have found 66 cracked bed plates, 63 broken columns and 5 cracked channel plates. Still, in almost all of these cases the breakages have occurred from carelessness on the part of the engineers in allowing water to become entrapped and freeze in winter when the boats were tied up, rather than from light construction.

We have also found 148 cases where the stern logs or pipes or stern bearings were defective. In most of these cases the defect is from decayed wood, caused by leakage, or from insufficient fastenings of the stern pipes in the stern logs.

Our inspection of pumps, piping and connections has been

especially rigid, and, while we have found very few cases of broken pumps, we have found many cases where the piping and sea connections were defective. There are 762 vessels on the lakes in which the sea connections are not fitted with non-return valves, so that water could not, either by accident or intention, be run into the vessel. This is a fault the seriousness of which has been especially illustrated during the past winter, when a great number of vessels were loaded with grain in the fall and used for storage during the winter at Chicago. In a great many of these vessels damaged grain was found in the spring, from the leakage through the sea connections, which if they had been fitted with non-return valves would not have occurred.

There are 153 vessels in which steam and water pipes pass through the coal bunkers without proper protection, and there are 92 vessels on which the fire apparatus is either out of order or insufficient.

Our survey of the electrical equipments has as yet been rather superficial, and has really amounted to only the listing of boats having such equipments; but we are now starting on a very much fuller and more rigid inspection of these equipments. We have found 312 vessels equipped with electric lighting apparatus. A number of these equipments are rather crude, and the installation and wiring far from satisfactory; and there have been a number of cases of damage to cargoes and vessels from fire started through defective insulation.

We are, of course, not at liberty to say very much regarding the ratings whicn have been placed on the different vessels on the lakes, but there are some points in regard to the ratings on machinery which are of interest and which we may divulge.

It was not our intention to use age as a factor in the rating placed on machinery, but to base the rate entirely on the construction of the machinery and its condition of preservation. From a table compiled from the ratings placed on the more than 1300 vessels, however, the fact is shown that age does cut a considerable figure in connection with the condition.

The highest classification given to any vessel built previously to our rules compiled for future construction is 100, and we rate from that down to 50 by points of five.

It is interesting to note that the boats on which the machinery is rated as low as 50 were built during the following periods: Three between 1860 and 1870; 4 between 1870 and 1880; 4 between 1880 and 1890, and 2 since 1890.

The rating of 55 is distributed about the same, although there are four boats built since 1890 rated as low as 55. This low rating on recently built boats is accounted for by light and faulty construction, and from the fact of their being very poorly cared for.

The highest rating given to any boat built earlier than 1870 is 85. The majority of those built between 1870 and 1880 rate from 70 to 90, and the majority of those built between 1880 and 1890 rate from 75 to 95, although there are 62 built during this period rating as high as 100. Most of the boats rating 90, 95 and 100 have been built since 1890.

In compiling rules for future construction it has not been our intention to create anything particularly new or to deviate widely from the rules adopted and maintained by the older classification societies, such as London Lloyds, British Corporations and Bureau Veritas, but it has been our aim rather to carefully select and adapt such rules as may have a special bearing on the peculiar requirements of the practice on the Great Lakes. In this respect we have taken the rules of the older societies as our basis, simplifying them where we deemed simplification possible and adding to them such items as seemed advisable to cover these special requirements, basing our alterations and additions on the data gathered from our survey of more than 1300 vessels now running on the lakes. These data showed us beyond question whether the rules which we took as our basis were sufficient or were more rigid than the requirements demanded.

We have divided the rules into four separate heads or sections,—viz, Engines, Pumps, Piping and Connections, Boilers and Electrical Equipment.

Under the first heading, Engines, we have deviated very little from the established rules of the older societies, for they cover very fully all requirements met with in lake practice. We have, however, where we could, simplified the formulæ for determining the sizes of the several parts, and have recommended, though we have not insisted upon, such items of more modern practice as the fitting of the propeller wheels on a taper tail shaft with feather and nut, and the use of taper and shoulder connections of piston rods in cross-heads; and have covered very much more fully than the older societies have the items of fastening of cylinders to columns, columns to bed plate and bed plate to seatings. In connection with these latter items we have compiled very simple formulæ for determining the strength of these fastenings, and have published, in connection with these formulæ, tables showing the

strength of studs and bolts of different sizes, such as are used in making these fastenings.

In these rules we have also covered very carefully the points of determining the minimum size of crank, intermediate and propeller shafts; of the thrust surface of thrust bearings, so as to entirely relieve the cranks of the engines from fore-and-aft strains; the fastening of piston rods in cross-heads, either by key or by nuts; the thickness and strength of cylinder walls and heads, and the proper staying of cylinder heads by ribs; and we have also called particular attention to the fact that cylinders and receiver chests must be fitted with relief valves of sufficient size to safeguard them from undue strain.

Under the heading "Pumps, Piping and Connections" we have covered those points, as to the necessary pumps, that are required by the older societies, and as to the strength of piping for different purposes; and, in addition to these points, covered by the older societies, we have included such items as—

First, that no pipes are to be carried through the coal bunkers without being properly protected.

Second, that in all steam pipes provision must be made to permit expansion and contraction to take place without unduly straining the pipes, and that all stuffing-box expansion-joints must be fitted with safety guard-bolts to prevent the end of the pipe from being forced out of the joint.

Third, that in order to have at all times full control of valves and pipes connecting engines, boilers or ballast tanks with the sea, they must in all cases be so arranged that water cannot, either by accident or by intention, be run into the vessel; and that, in cases where pipes are led or so placed that water could run into the vessel from either sea or boiler, they must be fitted with non-return valves.

Fourth, that all inlets or outlets in the side of the vessel near to, at or below the deep load line must be fitted with cocks or valves, fitted close to the side of the vessel. We have also insisted that all exhaust pipes from windlass, capstan, deck and steering engines, and from all auxiliary engines and pumps, must not be led through the vessel's side, but must be led to the main waste steam pipe, which should in all cases have a drain pipe led to the engine-room bilge or hot-well.

Under the heading of Boilers our rules have, of necessity, been made to comply as closely as possible with the rules laid down by the United States Board of Supervising Inspectors. We have, however, tried to simplify as much as possible these rules and

the formulæ for determining strength of the parts, and have added only such rules as we deemed necessary for safety from the insurer's standpoint.

The rules for boilers, of course, cover only the common types, such as firebox, Scotch and vertical cylindrical boilers; as, with the marine water-tube type of boilers, each maker has a special design of his own and the boilers having individual features, it was impossible to lay down hard-and-fast rules covering this type. To cover all such cases we have inserted the clause, "All other types of boilers than those referred to must be submitted to the board for approval." In this way we give the Engineering Department of the Register the opportunity of inspection and approval of the plans of all odd types of boilers before permitting them to be installed in modern vessels looking for our highest classification.

Under the heading of Electrical Equipment we have adopted almost verbatim the rules laid down by the National Board of Underwriters for the installation of wiring and apparatus for electric light and power, adding to these rules only such features as were particularly applicable to marine practice, one of the most important of which is the rule that all lamps in cargo holds must be on a separate circuit run direct from the switchboard, and with a pilot lamp on the switchboard to detect current on this circuit when the cargo hold is closed.

In this connection I might say that a number of losses to the insurance companies have occurred recently from damage to grain cargoes from faulty wiring and connections in the cargo holds, the lamps in cargo holds of many of the vessels now electrically lighted being simply branch lights, taken from the main circuits of the equipment.

In cases where this method of equipment is used the only way of switching off the lights in the cargo holds is by the local switches at the lamps, and after the cargo hold has been filled and closed it is impossible to tell, either from the engine-room or from the decks, whether or not the lights in the cargo hold are burning when the current is on the main circuit, and it is consequently impossible to tell whether or not there is any danger of fire in the cargo. Our other rules for electrical equipment are those common to all societies governing the apparatus and installation of electrical equipment for lighting and power.

In closing, I wish to say that this work, both in the inspection of vessels now on the lakes and in the compiling of the rules for future construction, has been exceedingly interesting and instructive, and it was a great pleasure as well as benefit to me to be

associated in it with such a man as Mr. Miller, who is not only so thoroughly competent to undertake such work but is also so conversant with the practice of construction of marine engines and boilers on the lakes for the past twenty years.

DISCUSSION.

Mr. Jos. R. Oldham.—About thirty years ago, when I was Engineer of the Bureau Veritas, the first triple-expansion engine was being built. You understand, I suppose, that the classification of a ship merely means giving her a character. Mr. Coffin described very minutely the examination of all the vessels on the lakes, but I would ask him whether good results were obtained from these examinations, for I did not hear him say what improvements resulted from them. It is a serious thing that within the past two years no less than six vessels have had their engines blown to atoms, and I should very much like to know whether Mr. Coffin or Mr. Miller can tell us anything about the cause of these accidents.

The suggestion as to a stop-valve between the engine and the boiler is a very wise one. Last week I was on a vessel where the captain wanted to fill one tank. The bottom of one was leaking. The bilge pump was working, and one of his tanks could not be filled because the pump was drawing water from another. Filling pipes should be quite distinct from emptying pipes. I do not know that I need say anything more, except to compliment Mr. Coffin very much on his paper. If any one wants a copy of my book, entitled "The Great Lakes Register of Shipping," I shall be pleased to present him with one.

Mr. Walter Miller.—It would be out of place for me to discuss Mr. Coffin's paper, but, owing to Mr. Oldham's remarks, I want to touch on this question of break-downs which is attracting so much attention.

Those who are interested in such matters seem very anxious to discover the cause of the trouble. These break-downs are very mysterious and unexplainable. Of course, we all know about water in steam pipes, etc., but just how it acts to cause the destruction of the pipes it is difficult to say. In the case of the steamer "Manitou," in which one of the two bolts in the cross-head broke, each bolt had material enough to do the work alone, provided it had the proper connection, but this bolt broke without any apparent cause. In the case of the "City of Chicago," the connecting-rod strap broke at the junction of the two brasses; and when the strap parted there was not more than 1-10 of the section

holding, as there was only a thin section of material left around the outside of the strap, and the balance of the section was gone. A fragment which remained was stretched like a piece of rubber, and the other side of the strap was bent at an acute angle without the least sign of fracture. In the case of the "Iron Age" the connecting-rod strap broke at the junction of the two brasses, the same as in the case of the "City of Chicago." In the case of the "State of Ohio" the connecting-rod broke at about 3 feet from the lower end of the rod where a band was clamped on it, to which the braces which steady the rod were attached.

In all of the above-described cases the material was good, as could be seen by the character of the break; and it had ample section to do the work, yet it failed. Just why these parts failed it is difficult for any one to tell, but such breaks are commonly attributed to crystallization.

THE "ECONOMETER."

By H. M. Kebby, Member of the Technical Society of the Pacific Coast.

[Read before the Society, October 7, 1898.*]

The process of making steam presents two problems: first, the production of heat from a given combustible; second, the utilization of the heat obtained; and it is regarding the first of these problems that we submit facts for consideration.

In every pound of coal a definite amount of heat is contained, varying as the quality of the coal varies; and the process of liberating this heat is known as combustion. To liberate all of the heat it is necessary to have perfect combustion, and the elements requisite for obtaining that result are unvarying.

In order to produce combustion, carbon, the vital element in the coal, must unite with oxygen, which it does in certain unvarying proportions. In the first stage of combustion one part of carbon unites with one part of oxygen, forming a combustible gas, known as carbon monoxide, and in this process about one-fourth of the heat is liberated. In the second stage the carbon monoxide absorbs another part of oxygen, forming a gas known as carbon dioxide, or carbonic acid, and in this process the rest of the heat is liberated. As there is 21 per cent. of oxygen in the air that is conveyed to the carbon, it is easily seen that perfect combustion would produce 21 per cent. of carbonic acid, since all of the oxygen would unite with all of the carbon and every heat unit contained in the coal would be liberated.

For many reasons, it is next to impossible to obtain perfect combustion in any steam boiler furnace, but it is possible to obtain and maintain good combustion with proper firing and correct manipulation of the draft and dampers. It is easy to see that the only test to be applied is that of determining the amount of carbonic acid present in the escaping gases, and that the value received from the burning of all coal is in exact proportion to the percentage of this gas. Chemistry has determined these values, so that when the per cent. of carbonic acid is known the value received from the burning of any coal can be ascertained; we annex a table showing these relative values, from which it is apparent that the difference between burning coal properly and improperly means many tons a year to a steam plant of any size.

*Manuscript received October 13, 1898.—Secretary, Ass'n of Eng. Socs.

In Europe, where coal economy has received the greatest attention, it has long been the custom to provide engineers with chemical apparatus, by which the percentage of carbonic acid could be determined at intervals. This determination, though irregular, proved of the greatest value, and led to the invention of the Econometer, which indicates continuously the exact percentage of carbonic acid contained in the escaping products of combustion. The value of having a continuous indication, rather than one obtained at infrequent intervals, can hardly be overestimated, for a constant guide to firing is thus obtained.

Carbonic acid is 50 per cent. heavier than air, and thus the greater the percentage contained in any given volume of flue gases the greater the weight of that volume. In the Econometer a sample of the escaping gases from the boiler is drawn continuously through a balance scale suspended in air, and the variations in weight that are produced by the different states of combustion are made to record the percentage of carbonic acid. The weight of this gas varies with the temperature, but in the Econometer the sample to be weighed and the air in which the weighing is done assume the temperature of the room, so that the proportion remains exact.

It is plainly evident that for each pound of coal a fixed amount of air is necessary for combustion, varying as the percentage of carbon varies in the different coals. For a pound of average quality about 125 cubic feet of air is necessary, and it is the inability to convey the precise amount to the furnace that prevents our obtaining and maintaining perfect combustion.

If too little air is admitted combustion becomes imperfect, because the carbon monoxide cannot find the necessary oxygen to complete its transformation into carbon dioxide; and this is the most wasteful condition of firing, for the largest part of the heat is given off in the second stage of combustion. This case is seldom met with in practice, for most boiler furnaces are supplied with too much air. Then the combustion is poor because there is a large amount of air passing through the fire, the oxygen of which cannot be consumed. This surplus air must be heated to the same temperature as the escaping gases, thereby absorbing the heat already generated, which should pass into the water contained in the boiler. The loss here may be compared with that occasioned by pumping cold water into a boiler, instead of heating it to the boiling-point by exhaust steam, as is usually done.

This loss of fuel shown in the annexed table, as calculated and proved, can be caused in a variety of ways, and is to be sought for

in all of the accessories of the furnace. It may result from an excessive or defective draft; from faulty grates or wrong proportion of grate surface; there may be defects in the boiler setting or in the fire or ash-pit doors. The proper thickness of fire, varying with the many different conditions surrounding all steam plants, must be determined.

By first obtaining the percentage of carbonic acid in the gases produced with ordinary firing, and then experimenting with the boiler equipped with the Econometer, any fireman can soon ascertain the proper thickness of fire and draft necessary to insure good combustion. If, with a high percentage of carbonic acid, the gauges show too much steam, a case often experienced in practice, it is evident that the grate surface should be reduced, which can be done by bricking up at the back end of the ash pit.

A very common source of waste is the formation of holes in the fuel on the grate, and the Econometer is a never-failing indicator of the presence of such holes. By drawing samples of gas from the entrance and exit of the flues, and comparing the percentage of carbonic acid, any existing defects in the setting and brickwork will be discovered.

The following table shows the loss of heat and fuel, with from 2 to 15 per cent. of carbonic acid (CO_2) in the combustion gases.

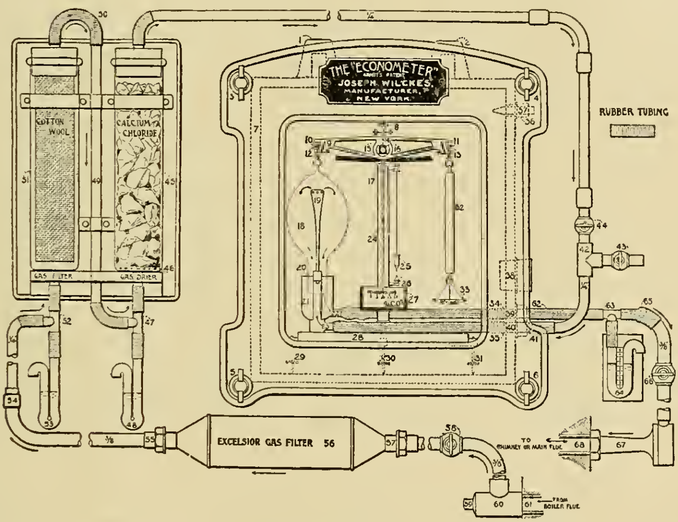
The proportion between the amount of air actually used and the theoretical amount required is, in the case of coal (according to Bunte), $\frac{18.9}{K}$, K being the per cent. of carbonic acid in the gases.

For Coal of Medium Quality.

If the "Econometer" shows	2	3	4	5	6	7	8	Per cent. carbonic acid.
Then the quantity of air passing through the flues is	9.5	6.3	4.7	3.8	3.2	2.7	2.4	Times the theoretical requirements.
With a surplus of air of 30% or about 166 Cu. Ft. of necessary air per lb. of fuel, there will still be a further excess of about	1977.6	1212.5	960.5	606.3	538.8	395.5	310.8	Cu. Ft. of superfluous air heated to a temperature of usually 518° Fahrenheit.
And the loss of fuel at 518° Fah. amounts to	90	60	45	36	30	26	23	Per cent.
If the "Econometer" shows	9	10	11	12	13	14	15	Per cent. carbonic acid.
Then the quantity of air passing through the flues is	2.1	1.9	1.7	1.6	1.5	1.4	1.3	Times the theoretical requirements.
With a surplus of air of 30% or about 166 Cu. Ft. of necessary air per lb. of fuel, there will still be a further excess of about	197.8	169.5	113	84.8	56.5	28.3	0.0	Cu. Ft. of superfluous air heated to a temperature of usually 518° Fahrenheit.
And the loss of fuel at 518° Fah. amounts to	20	18	16	15	14	13	12	Per cent.

One glance at this table shows conclusively the immense practical advantage of the Econometer, and will convince every expert and coal consumer that this apparatus is a most important equipment of every steam boiler.

Referring to the cut, the gas is taken from the combustion chamber of the boiler, not less than 9 feet back of the bridge wall, by the connection marked "61." It then passes through the filter marked "56," which is a brass filter case packed with excelsior; this takes the coarse particles of soot from the gas. From this filter the gas passes to the filter marked 51, which is a glass tube of about 3 inches in diameter, containing a wire gauze tube suspended so that there is a clear space all around between it and the



wall of the glass tube. This gauze tube is packed with cotton, wool, and the passage of the gas through it removes the remaining particles of dirt. The gas then passes to the filter marked 45, which is a glass tube filled with calcium chloride; the passage of the gas around the lumps of chloride frees it from moisture, which drops to the siphon marked 48, and overflows when the siphon fills up. The gas, now thoroughly cleaned and dried, passes to the weighing globe marked 18 through the $\frac{1}{4}$-inch pipe and up through the perforated glass tube marked 19. From the weighing globe the gas passes out through the cup-shaped vessel marked 21, and the rubber tube to the $\frac{3}{8}$-inch pipe connection to the stack, or to the main flue, beyond the damper. This $\frac{3}{8}$-inch pipe is connected to the stack through a brass aspirator marked 67, the purpose of the aspirator being to create a draught slightly in excess

of the flue draft, thus insuring a constant flow of gases through the instrument. Between the chloride filter and the weighing globe is shown a tee 42 and stopcock 43, which are so placed that by shutting off stopcock 44 and opening 43 the gases in the instrument will be drawn off and atmospheric air take their place. This will avoid the discoloring effect the gases would have on the glass should they not be withdrawn when instrument is out of use, and also test the balance, which should come to zero when only air is present. The instrument is calibrated by changing the amount of iron filings on weight pan 33 by means of a magnetic needle through the opening in the box marked 38, which is closed by a rubber plug when not in use. The scale for weighing the gases is enclosed in a cast iron box with glass front, which is airtight with the exception of a small glass tube 37, packed with cotton wool, to allow a small quantity of air to fill the box, thus keeping the gases in their proper channel. Between the box and the stack is a draft gauge 64. By turning off the stopcock 66 the stack draft will be shown; then by opening this cock slowly until the draft is increased about $\frac{1}{8}$ of an inch by the aspirator, the gases will flow through the instrument with the proper speed. Should the gases pass too quickly, they will impinge on the weighing globe and give an unsteady motion to the scale balance, thus defeating the primary object, which is to show the percentage of CO_2 on the vernier by means of the pointer attached to the balance.

Below is the report of the Franklin Institute of Pennsylvania on this instrument. The report gives a good description of the apparatus and its working:

REPORT OF THE COMMITTEE ON SCIENCE AND THE ARTS, FRANKLIN INSTITUTE, INVESTIGATING THE INVENTION OF MAX ARNDT, OF AIX-LA-CHAPELLE, GERMANY. NO. 1973.

HALL OF THE FRANKLIN INSTITUTE.

PHILADELPHIA, September 1, 1897.

The Franklin Institute, of the State of Pennsylvania, for the promotion of the mechanic arts, acting through its Committee on Science and the Arts, investigating the merits of Arndt's Econometer, reports as follows:

The sub-committee appointed to investigate the operation of an instrument for the measurement of carbonic acid gas (CO_2) escaping in the flow of the products of combustion from a steam boiler furnace have performed the duty assigned to them, and beg to report as follows:

This instrument is known under trade name of Econometer, and is the invention of Max Arndt, of Aix-la-Chapelle, Germany, by whom it was patented in the United States October 16, 1894.

Through Mr. Joseph Wilckes, of New York city, the inventor's American representative, a request has been presented to this institute for an

examination into the merits of the instrument, for the purpose indicated above.

The apparatus consists of a balance beam, carrying at one end a gas vessel provided with a neck open at the bottom, a gas delivery pipe projecting upward into this vessel being fixed and supported in it in such a way that upon the oscillation of the balance beam the gas vessel may move freely up and down without coming in contact with the upward projecting pipe through which the gas flows into the vessel.

The gas vessel is balanced by a compensating vessel suspended from the opposite end of the beam, also open at the bottom, and equivalent to the gas vessel in its capacity in conjunction with small weights placed on a pan under the compensating vessel, that the pointer of the beam shall move to zero on the scale when atmospheric air is drawn through the apparatus.

The gas vessel being open at the bottom, so that the pressure within it is always the same as that without, fluctuations of pressure and barometrical readings have not to be considered in the use of the apparatus; likewise fluctuations of temperature do not affect its action, because the gases passing slowly through the apparatus quickly take the temperature prevailing in the narrow gas passage.

The fluctuations which take place in the density of the gases round the fixed pipe in the gas vessel cause up-and-down motions in the latter vessel, which are shown by the pointer on the scale. This pointer is rigidly fixed to the beam so as to follow the movements of the gas balance; it oscillates in front of a divided plate or scale, indicating units of weight by the distance between its dividing lines; or these distances shall, in conjunction with the pointer, indicate a particular percentage volume of a particular kind of gas in a gaseous mixture. For example, the instrument placed at the disposal of this committee had divisions on its scale for indicating the percentage volume of carbonic acid gas, for the purpose of ascertaining the percentage of such gas escaping in the products of combustion from a steam boiler furnace.

Two tubular orifices are provided, one for the inlet and the other for the outlet of the gases, the former connecting by a flexible tube with the vertical fixed pipe in the gas vessel and the latter by a flexible tube with the cup-shaped vessel situated below the gas vessel. The source of the gas supply is placed in communication with inlet leading to the gas vessel, and a suction apparatus of any suitable kind in communication with outlet from the cup vessel under the gas vessel. A portion of the air present in the casing is first drawn off; that is to say, the air is exhausted by suction to so much of a vacuum as corresponds to the strength of the suction at the cup vessel under the gas vessel. This rarefaction being obtained, the gas to be weighed passes into the gas vessel, filling it, and then out of this vessel into cup vessel below.

The gas balance is inclosed in a casing with a glass front for the purpose of observation; this casing is provided with an aperture closable by a plug, upon the removal of which the weights may be adjusted as required. Further, at the top of the casing there is an aperture filled with cotton wool for the gradual and continuous admission of atmospheric air thereto. The balance is, therefore, located in a nearly air-tight chamber, with its several parts so arranged that when the gases to be weighed flow through a vessel

forming part of the balance it may operate without resistance and with great sensitiveness.

The determination of the percentage volume of a particular kind of gas contained in a gaseous mixture is only practicable by means of the apparatus when the specific gravity of the gas sought for is different from the specific gravities of the other gases preponderating in the gaseous mixture, but such other gases may be of like specific gravity among themselves. This, for instance, is the case with respect to the smoke gases of steam-generator furnaces, which gases are made up of oxygen, nitrogen, carbonic oxide and carbonic acid. Of these, the first three are of nearly the same specific gravity, approximating that of atmospheric air = 1. On the other hand, the specific gravity of carbonic acid = 1.52, and is therefore about one-half heavier than atmospheric air; and a smoke gas mixture must consequently be heavier the greater its contents of carbonic acid. With perfect combustion of the carbon contained in the fuel and with the air of combustion measured in a theoretically accurate manner, the carbonic acid of the smoke gases amounts to about 20 per cent. of the total volume; but it is less than this when the air of combustion is supplied in a larger quantity. If now the zero line of the scale has such a position that it coincides with the pointer when only atmospheric air is present in the gas vessel; if, further, the end line or division of the scale has such a position that it coincides with the pointer when atmospheric air mixed with carbonic acid to the extent of 20 per cent. of the total volume, as determined by a chemical analysis, is drawn through the gas vessels; and if, further, the scale has twenty corresponding divisions, then the movement of the pointer from one division to another will correspond to the difference in the weight of the gaseous mixture in proportion to the percentage volume of carbonic acid; and, accordingly, in the practical use of the apparatus, that is to say, when smoke gases are being conducted through the gas balance, the contents of carbonic acid, as indicated by the pointer in a sufficiently accurate manner for practical purposes, may at any time be read off from the scale direct. If, for instance, the pointer points to the division line marked 12 on the scale, this would indicate that the smoke gases drawn through the vessel contain 12 per cent. in volume of carbonic acid; that is to say, the volume of the latter would amount to 12 per cent. of the whole volume of the smoke gas mixture.

If the smoke gases of a steam-generator furnace when passing to the chimney have a temperature of 270° C. (or 518° F.), and 12 per cent. of their total volume consists of carbonic acid, the loss of heat amounts only to about 15 per cent.; but if at the same temperature the carbonic acid contents amount, for example, to only 4 per cent. of the volume of the waste gases this would show a loss of heat of about 45 per cent., due in a great measure to the heating of an excessive quantity of air for the combustion of the fuel. Hence it results that the gas balance herein described is of great importance as a controlling apparatus for steam-generator and other furnaces, and also for obtaining the specific gravity of other gaseous mixtures by direct weighing.

A practical test of this instrument was made by the investigating committee at the Baldwin Locomotive Works, in this city, with the results given in the annexed table. The boiler furnace from which the supply of gas was taken was one in which anthracite coal was used, the boiler was of

the Babcock & Wilcox manufacture, and its furnace setting was in no respect different from their ordinary practice. The gas analysis was by Prof. Harry F. Keller, Ph.D., of this city; each analysis was made immediately upon the withdrawal of the samples and at the place where the other tests were being conducted.

These comparative tests satisfied the investigating committee as to the substantial accuracy of this instrument. The recorded variations given in the annexed tables show discrepancies so trifling that if the Econometer were used in the management of steam boiler furnace fires no considerable loss would occur by reason of the difference between the Econometer reading and the chemical analysis. A saving of fuel would result because of a better and more intelligent management of fire and dampers, allowing less surplus of air to pass through the furnace than would ordinarily be the case.

The Econometer works continuously, and shows automatically the percentage of carbonic acid in the gases, thus enabling the fireman to see at all times the more or less favorable conditions of combustion.

The claims made for this instrument have, in the opinion of the investigating committee, been fully substantiated in its presence, and the Franklin Institute therefore awards the Elliot-Cresson Medal to Max Arndt, of Aix-la-Chapelle, Germany.

Adopted at the stated meeting of the Committee on Science and the Arts, held Wednesday, October 6, 1897.

John Birkinbine, *President.*
Wm. H. Wahl, *Secretary*

Countersigned by James Christie,
Chairman of the Committee on Sciences and the Arts.

DISCUSSION.

President Molera.—At the Beale street wharf an instrument was put on in connection with a system of smoke burning, and it showed from 6 to 9 per cent. of carbonic acid. By regulating the draft and stopping up the leaks that were found in the brick walls of the furnace, and by cutting down by one-half the air that entered the furnace, we very shortly increased the percentage of carbonic acid to 17 per cent.

In this machine is there any way of localizing the defects of combustion and telling just where it occurs?

Mr. Kebby.—Of course, we can discover quite readily any defects in the setting, if any are there. If there is a crack in the boiler wall, and the air rushes in, the Econometer, applied in two different places, will show the difference in the carbonic acid. The moment more air is admitted it reduces the percentage of carbonic acid. If the per cent. of carbonic acid is low, we are getting too much air, and we must regulate the damper in the stack and the ash-pit doors, and cut down the draft as much as possible. When we get too high a percentage of carbonic acid, and the boiler makes

steam too rapidly, we must cut down the size of the grate. In some of the establishments in Europe the size of the grate has been reduced one-third. Of course, that means that they had previously been burning more fuel than was necessary.

The cotton in the filter must be changed once in about two months. The calcium chloride will probably need renewing more often. It depends upon how close to the boiler the machine is, and upon how dirty the coal is. The chloride should generally be renewed when it is melted down about one-half.

I placed the first Econometer about a month ago, and I have just sent another one out. It is rather hard to place anything here until people can see for themselves just what it is. I do not expect to have much trouble in placing a great many as soon as the people can examine it thoroughly for themselves. Thus far I have had no trouble in getting engineers to understand the benefits which can be obtained by the use of the instrument.

Mr. Grunsky.—I have read of another system of weighing, and that was by means of an inclined tube containing water. The measurement was obtained or shown by the displacement of the water. The details of the instrument I do not know anything about.

Mr. Kebby.—That is what we call a gas-absorbing econometer. It does not make a continuous analysis as the Econometer does. In the gas-absorbing econometer the gases are pumped into a receiver in the machine, and then those gases are absorbed by the liquid; and, as they are absorbed, the air in the chamber is displaced or rarefied, and the water in the tube is raised. The tube is graduated to show the percentage amount of carbonic acid.

Mr. Grunsky.—In the appliance I have in mind I believe the weight of the gas displaced the column of water. In order that the displacement might be perceptible, the tube containing the liquid was placed nearly horizontal in order to have it as large as possible.

Mr. Kebby.—As far as I know, this is the only instrument of the kind which continuously works automatically. This gas-absorbing machine works nearly as you say, but, of course, it is not automatic. You can readily understand that when the weight of gas displaces the water the gas has to be pumped out. There is no means of escape.

Mr. Grunsky.—There was a small weighing contrivance, and I think there was a continuous flow of gas through the machine.

Mr. Kebby.—The scale on this machine is very delicate. It works practically in an air-tight chamber, and the knife edges are all of agate.

Mr. Molera.—There is no contrivance to give a graphic record?

Mr. Kebby.—No; but I have been studying the problem of providing one. The great difficulty in that direction is the delicacy of the scale. A ray of light thrown on a point might be photographed. It might be worked on the same principle as a galvanometer for delicate scientific measurements. That would certainly do for work of that kind. But for ordinary, every-day use I am afraid it would be too expensive.

Mr. Molera.—I suppose everything needed is supplied with this machine?

Mr. Kebby.—The owner of the plant supplies the pipe, which is a very small item. The price of the Econometer is $150. The filters, of course, can be placed anywhere, as, for instance, near the boiler, and the scale is placed within a cast iron box. The Spring Valley Water Works has one of these instruments in use at Black Point. I suppose it will work where oil is used as fuel. I do not know that it matters whether oil or wood or coal is used. The gas-absorbing apparatus is used for marine purposes. It must be very steady. If the position of the box or any part of the weighing apparatus is changed the instrument is thrown out of balance, but in any ordinary boiler room it can be so placed that it will not be disturbed. Only a delicate instrument will do the work properly.

Mr. Grunsky.—Does the smoke itself interfere when the combustion is imperfect, and when the air is highly charged with carbon that has not been consumed? Does that materially affect the gas filter?

Mr. Kebby.—If the gases are very dirty and have a tendency to clog the filter, the rubber tube can be disconnected at the instrument, and then, by blowing back through the filter, the dirt from the gases readily passes out. That is the common usage. If the coal is dirty the pipes between the furnace and the instrument will have a tendency to clog if left for some length of time, but this can be avoided by disconnecting the rubber tube, as I have said, and blowing through the pipe.

Q.—How long has this instrument been in use?

A.—I think it was first brought out in Europe in 1893. It was first brought to this country in 1894.

THE ELECTRIC MOTOR IN SHOP AND MINE.

By Clarence M. Barber, Member of The Civil Engineers' Club of Cleveland.

[Read before the Club, October 25, 1898.*]

The highest point that science has reached in this century and especially in our day is marked by its exploitations in electrical engineering. In this field, but standing a little back from the foreground, we find the electric motor.

It is not my purpose to enter into a theoretical discussion of this machine, but rather to note a few points bearing upon its present status in the shop and mine, and possibly to bring out a few points that may be of interest to the engineer who is not an electrician but who is interested in electrical power transmission.

The advent of the electrical motor has been so sudden and its field so wide that in many places its application has been accidental rather than otherwise, and we have just reached a period in the progress of electrical engineering where the electric motor is beginning to overtake its history, or in other words, it is just now doing what its over-sanguine friends claimed it was doing several years ago.

Street car propulsion early demanded attention and contributed perhaps more than any other one thing to the development of a hardy, healthy class of motors. The present status of the street car motor leaves but little more to be desired. Small motors, and in a few cases large motors, have been in use for other purposes in the last few years to a limited extent, especially in the shop and mine, but now the electrical engineer is going deeper into the problem than ever before.

The development of the shop motor at the present moment is remarkable. We seem to be entering upon a new era.

It is American-like to push forward anything that is worthy the attention of bright educated minds and capital. American activity and brains have taken hold of not only the conversion of mechanical energy into electrical energy, but the re-conversion of the latter into mechanical effect. The result of this is that the application of the electric motor to the driving of almost every class of machinery is being pushed.

The claims which the electric motor has upon the shop and mine are based upon the ease with which it can be applied to

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almost all the purposes for which power is required, economy of installation, saving of power and many other incidental advantages.

The absence of overhead shafting and belting in many cases is a great consideration, especially as these often prevent or interfere with the use of overhead cranes. In fact, large traveling cranes are now indispensable in all shops where heavy work is handled, and these preclude the use of belting and overhead shafting within the areas served by them. Even in case of small jib cranes the belting and overhead shafting are almost invariably in the way.

This consideration alone in many shops is of sufficient importance to outweigh any prejudice that may exist against electric power transmission, especially since the motor has arrived at the stage where it is able to fulfill the requirements. The removal of belts and shafting greatly favor cleanliness and better light, and the roof supports, not being required to carry shafting, allow higher ceilings and better designed buildings. The writer, however, would not convey the idea that all shafting and belts are to be entirely dispensed with, although under some circumstances no shafting or belting need be used.

It is a valuable consideration to be able to place a machine at any angle with the meridian or at any distance from the source of power.

The removing of a machine from one part of the shop to another if it has its own motor attached to it is not a serious matter. Large machines, such as punches and shears, are now sometimes built with motors attached and arranged so that the whole may be turned on ball bearings about a vertical axis through any desired angle.

The dispensing with belting and overhead shafting is accomplished by placing a motor on each machine. This makes each machine complete in itself. It is started or stopped, made to run fast, slow, or reversed without regard to any other piece of machinery. This is an ideal condition both as regards each machine in its individual relation to the whole shop and as to its consumption of power.

The first cost of an electric shop power installation is in most cases more than an installation with shafting and belting. The cost of maintenance is less. The comparative cost of transmitting power by the two systems is of course the most important question involved. Theoretically the power lost in transmission by means of shafting is small. Some tests by the writer show that it may be below 10 per cent. in a shop of considerable size under

favorable conditions, but it seems diffieult to realize as good results under such conditions as are usually found. Aeeording to Professor J. J. Flather, the loss of power in shops due to transmission by belting and shafting averages about 40 per eent. of the total power developed. He mentions among others the ease of the Baldwin Locomotive Works, where 80 per eent. of the power is lost in transmission through shafting and belting. He also notes the ease of J. A. Fay & Co., woodworking machinery, where only 15 per cent. of the power developed is required to drive the shafting. In the first case the loss is doubtless exeeedingly high; no other case that he mentions show over 50 per eent., and the next to the lowest is 23 per cent.

Henthorn gives the result of 55 tests in New England shops at 26 per cent. loss; Fessenden gives the mean of 108 tests at 69 per eent.

These results show a great variation, which is probably due to variation in the distanee over which the power is transmitted, to the eharacter of the maehinery driven and in a great measure to the alignment of the shafting as well as to the lubrieation. Added to these is the personal equation of the party making the tests.

It seems to the writer that we may assume as a fair average the loss of power by transmission through shafting and belts for the purpose of this paper to be 30 per eent.

In regard to the losses through transmission by eleetricity. These losses are: the loss in the generator, the loss in transmission through the line and the loss in the motor. This includes two transformations.

In the first of these, the loss in the generator, if it is a well-designed machine and running under a full load or a load that is not too far from that for whieh it was built, need not be over 6 per cent.

In ease of the loss by transmission through the line wire this is determined by the amount of copper in the line and the potential of the eurrent. As the latter in shops is usually a constant quantity and generally about 225 volts, the loss will vary with the amount of copper. It is not diffieult to confine the average loss to within 6 per eent. The third loss, that in the motors, will be somewhat more than that of the generator, due to greater variations of load, and on aeeount of greater number of maehines. The losses that are inherent in the motors themselves will be somewhat greater. The writer thinks the third loss should not average more

than 10 per cent. This would make the total average plant loss equal 22 per cent.

There are reliable companies that install electric power transmissions who advertise that their average plant losses do not exceed 15 per cent.

While long lines of shafting are almost sure to become out of line, and deteriorate from other causes, electric wiring when well put up, and in fact dynamos and motors when properly installed and cared for, and not overloaded so as to raise their temperatures so high as to endanger the insulation, will remain practically permanent.

There is an incidental point in favor of electric transmission that is very important. It is noticed in all shops that there are always a number of machines that are not running; if electric transmission is used the time that these machines are idle is a credit to the power plant, and as this quantity is within certain limits a constant, it follows that the engine and dynamo may safely be reduced in size on this account.

As an example: The American Lithograph Company, of New York, has a total capacity of engines of 660 horse power, a total capacity of generators of 590 electrical horse power. The rated capacity of all their motors is 847 horse power, and beside this they have 3000 incandescent lamps and 140 arc lamps. Their total generating capacity is only about 50 per cent. of what would be required if every motor and every lamp were on at the same time and every motor had its rated load.

What is still more remarkable, it is stated that their average load is only 17.6 per cent. of the rated capacity of all arc, incandescent lamps and motors, and the maximum load is 32.7 per cent.

The above is of great importance to power companies, as it enables those who supply current for a large number of small motors that are used for various purposes, as is the case with many power plants, to sell from two to three times the amount of power that they are able to generate.

The fact that the energy absorbed by the motor is proportional to its load also contributes toward reducing the load on the generators. Taking all these points into consideration it is not difficult to see how the above-rated results are obtained.

Another incidental point in favor of electric transmission is the fact that it is very flexible. The motors are capable of a variation of speed over a wide range. Motors with shunt wound fields are built for a constant speed that is predetermined, or they

may be run at any one of say six constant speeds forward, or two or more back-up speeds, the strengthening or weakening of the fields being easily controlled by a rheostat. This permits simplifying a machine where more than one speed or reversal of motion is required, less intermediate gearing being necessary.

The series wound motor resembles in the matter of speeds an engine without a governor. It must be controlled by the hand of the operator, or run under a constant load. Motors of this class respond quickly to the movement of the rheostat and are used wherever the hand of the operator controls every motion, such as for traction hoisting, cranes, etc.

The recent advancement in the development of the multiphase current motor shows that a great deal has been accomplished along that line, and but little seems to remain to be done before this beautiful form of motor will compete with continuous current machines.

For some time after the introduction of electric power transmission it was difficult to obtain slow speed motors. In fact it is only recently that motors have been on the market that can be said to run at slow speeds. This was not due entirely to the inability of manufacturers to produce such motors, but to the fact that they were generally occupied with other problems. Now, however, the want is supplied and motors of even small power can be obtained to run at 150 or even 100 revolutions per minute. Of course slow speed motors are like slow speed engines, they are larger and more expensive than those made to run at the higher speeds.

It is always best for the engineer who is designing machinery which is to be electrically driven to favor the electrician by using as high a speed as is consistent with other considerations, at least not to gear down toward the motor.

The electric motor early found its way into coal mines, and now does the hauling of the coal from the interior to the tipple, and the hoisting or pumping, as well as the drilling or undercutting. Freight on coal is not an item of expense near the slack pile at the mouth of the mine, so long distance transmission is seldom required at coal mines.

In gold and silver mining the most important work of all cannot as yet be performed by the electric motor. The diamond drill works well when driven by electricity. It is largely used for prospecting and occasionally for sinking of shafts, but it cannot take the place of the percussion drill. Many attempts have been

made to displace the pneumatic percussion drill by an electric drill, but, so far as the writer is informed, without success.

That an electric percussion drill can be made there is no doubt, but none have yet been made that fulfill the requirements. The fact is, the pneumatic percussion drill has been brought to a high degree of perfection, and it is very doubtful if it will ever yield its place to another. The exhaust air from the pneumatic drill is an advantage in mines, but not a sufficient cause for retaining the air drill if electricity could do the work as well.

However, the electric motor is not compelled to stand entirely aside even on the question of drilling granite rock. Wherever a question of long distance transmission is included in the problem, the electric motor comes in for its share, and is invited to stand behind the pneumatic drill and drive the air compressor. This, of course, introduces a second transformation of energy, but it cannot be avoided at present, except where the compressor can be driven directly by steam or water.

The great problem of producing a governor that will regulate a water power under varying loads has been brought so near to a solution that the water powers of the mountain mining regions of our country are now available for producing power that is to be electrically transmitted from the rivers and smaller streams up the steep slopes of the mountains to the points where gold, silver, lead and copper are mined.

DISCUSSION.

PROF. C. H. BENJAMIN.—I have been very much interested in this subject, and have made experiments along some of these lines. Mr. Barber has quoted some figures with regard to friction of shafting in shops. Several years ago I made a number of experiments in this city to determine the friction of the shafting as compared with the work being done. I visited a dozen or more establishments, some using large and some small machines. The largest amount of power used in driving shafting was about 80 per cent., and the smallest amount was 14 per cent., the average for the whole number of estimates, including both light and heavy machinery, was about 55 per cent. The results of these experiments have been quoted by electrical manufacturing firms to argue in favor of electric motors. Now, while I believe in electric motors in shops, I do not believe that this is the principal reason for their introduction. In nearly every establishment the expense for power is small; in some it is only 1 per cent., including the wages of the men, and in the majority it will fall below 5 per cent., so that a saving of even 50 per cent. in the coal bill is not so large an item.

The principal reason for the introduction of electric motors into shops is the fact that it will, in many cases, increase the output per man per machine. It will make it cheaper to manufacture, to build machines, or whatever the production may be, of that establishment; the mere question of saving power is a minor one.

The principal advantage is in the matter of flexibility, the ability to extend the plant at any time, to move any machine in any direction, and the entire freedom from the necessity of alignment. One advantage is the use of the crane to handle heavy work. In one establishment the principal reason for the introduction of the electric motor was that traveling cranes might be used. The saving by using cranes instead of men has been enormous. I have brought with me copies of two papers, one on "Friction H. P. in Factories," and the other "Electricity *versus* Shafting in the Machine Shop," and I would be glad to have the members help themselves to these papers.

Mr. C. O. Palmer.—If there is one place more than another where electric motors are specially useful it is in coal mines. There we want light, and electricity will furnish all necessary. We want power for hauling, and it answers this purpose fully as well underground as on the surface. In thin (4 ft. thick) veins where we should otherwise have to take the top down so that the mules could pass through we can run an electric motor without doing so. This is a large saving of expense.

In the matter of fans, if the fan is located near the boiler house it is an easy matter to run it by steam power, but sometimes we wish to put in a fan to ventilate a long distance from the boiler house, perhaps a mile. We can simply run an electric wire and put the fan in, and in that case it requires only one man to look at the motor occasionally. Again, in the matter of pumping, by using electricity the pumps may be situated a long distance from the shaft, and the water may be pumped by electric power by simply attaching the motor to the pump; this saves a great deal of hard work. One very large item of expense in coal mining is in the amount paid the miners for digging the coal. Here coal cutters run by electric power have been introduced, and the saving is about one-half that which is paid to the miner, the remainder going to pay for operating the plant, and the interest on the same. This is probably where the greatest economy is shown, and so much so that in some plants where electricity is employed this is its only use.

Mr. I. H. Sherwood.—In making some tests recently I visited a shop where there was a great deal of heavy shafting.

There were eight long lines of shafting running from $2\frac{1}{2}''$ up to $4\frac{1}{2}''$ in the shop, and the shortest one would probably be 50 ft. or 60 ft., the longest being 120 ft., or more, and the belting was very heavy. One belt was 16″ and about 35 ft. between centers, a very long span for such a heavy belt. The other belts, taken off from the main shaft to run the machines, were large belts 6″ and 8″ wide. Also there was a large pair of bevel gears, which were used to transmit quite a large share of the power, and the surprising part was that the friction was about 70 H. P., including engine friction, as shown by the indicator cards. After deducting a fair amount for the engine friction, there would be only about 35 or 36 H. P. for the shafting friction, or only about 10 per cent. of the total H. P. of the plant. It was a result which I did not expect, and I repeated all my experiments to prove my work.

I then investigated and found that the proprietors had made one of the best of investments. Their chief engineer was a thorough engineer. He had taken care of the shafting, and also installed it, and his orders were for one of his assistants go around the shop every month and line up every bearing. It did not take long to do it, and it was a good investment. The result was that while we were called in principally to give them the best method of installing electric power we advised them to keep their power just as they had it, and made some minor changes in other matters.

Mr. J. L. Gobeille.—In a shop where a few of the large machines must be run night and day, and nothing else is run night and day, I think the machines should be run by motors, each machine separately; it saves the power, the wear and tear on the shafting and danger of fire. At Russell & Co.'s plant, in Massillon, everything is done with electric motors. Each blower in their foundry is run by a motor. Their foundry is quite a long way from the main building, and there is no steam engineering connected with it. That is one of the shops where they have big things to turn out. I know of one woodworking machine that is running 4500 or 4600 revolutions per minute. In cases of this kind I believe it would pay, if a man had the nerve and money, to run these machines separately. I never saw it in print, and never heard it discussed, but I know that you cannot run a very fast machine and a slow one from the same shaft and have them both run satisfactorily. We can countershaft off when we have trouble until it runs right. Sometimes it takes quite a while to adjust everything properly. If we had motors I suppose we should not have that trouble. In mines I do not see how anything else can be

used. When we get the heating problem down, as we will some day, nothing will be used but electricity. When we can heat and light and run our tools from one plant economically then the millennium will be here.

Mr. J. A. Bidwell.—Some remarks have been made in regard to pumping water by electricity. I would ask whether any engineer here has had experience in that line, and how electricity is applied to a reciprocating motion?

Mr. Frank Houghton.—A few years ago I was manager of a plant in Dayton. It covers about four acres, and had four or five engines in different portions of the shops, and possibly averaged 1000 H. P. After going over the shops and figuring on installing motors to take the place of the engines I found that I could safely make a guarantee to furnish 500 H. P. in generators, or two 250's, to take the place of 1000 H. P. in engines, and if it was found, after the plant was started, that it required more power we would furnish any additional power free of charge, we were so sure that the 500 H. P. would do the work. The hard times came on at that time, and the company did not put in the plant, but it has since done so, and is running practically under that guarantee. Mr Barber spoke of the twist drill; I installed a plant at Amherst Stone Quarry a few years ago, and put in an electric drill. We found it worked well under the alternating current, except when they had to drill any great length of time, and then the drill would shift to one side, and the current was not strong enough to pull it out, and they had to discard the drill on that account; but for any short distance it was very much more satisfactory than the steam drill. There is one very remarkable thing in the efficiency of motors. With 100 H. P. in a motor and 100 in an engine, the efficiency of the motor would be, say 90 per cent. and that of the engine, say 70 per cent. Now, when there is a half load put on the motor, the efficiency is practically the same, possibly within 5 per cent. to 10 per cent.; when it is down to one-fourth load the efficiency is about 40 per cent. In the engine the efficiency at one-fourth load is at zero,—it is lost,—the whole power is consumed in running the engine itself. That is the result of the test made by the company I was with.

Another item that should be spoken of in favor of the motor in large shops where a large amount of shafting and belting is used is the cost of repairs to belts. It is generally said we can make so much of a saving in the coal bill, but the bill of keeping up the belts is very large, and that all goes to the credit of the motor.

Mr. John M. George.—I have been for many years one of

the most enthusiastic advocates of the electric motor, but we ought to be careful in accepting some of the statements made. The statement was made that the difference between 80 and 15 per cent. ought to go to the credit of the motor. I beg to differ. We would never dream of putting in such a plant as I have seen involving 80 per cent. loss, and such a plant as I have seen with 15 per cent. loss. I have seen many establishments where the loss has come up to 80 per cent., but they were not properly installed.

When I was with the Bullock Company we frequently made inspections, in some of which we found 80 per cent. losses. A great many of these were in machine shops. A machine shop is a peculiar installation; the power is required to be very heavy at times, but the bulk of the time very light. The average efficiency of shafting would not be more than 30 per cent. or 40 per cent. At Carnegie's they had about 4500 H. P. motors, and they were driven by 750 H. P. generators. That seems like a startling statement. If they had been steam engines it would have required about 4500 H. P., but the explanation is simply that they were widely scattered. With regard to saving, it is not merely in the coal bill, but in efficiency of service, keeping the shop clear of impediments and admitting more light. The more pleasant you make the shop the better work you will get out, and that is one of the great arguments in favor of the electric motor, because it enables us to remove the dirt from the shop. Another thing is the flexibility; we can put motors where we can put nothing else. A shunt motor, if working steadily, will show great efficiency, but when we vary the speed, as in ironworking, then the efficiency disappears. We have not yet found an efficient means of regulating the speed as required by machine tools. The series motor is well as long as it is governed by hand, but when we slow down a motor by resistance a serious loss takes place. The current is divided into three parts, the first part of it is choked back by the resistance, and another part is forced through the resistance, and there is where the loss takes place. We lose energy in the form of heat. I would like to know whether there is any means of regulating an electric motor in any other way than through the loss involved in resistance. I also would have liked to hear whether any steps have been taken toward designing a motor which will run steadily under the different speed conditions, and can be regulated to the degree of speed required, to cut material at different velocities of lathe.

Mr. Houghton.—The shunt motor is regulated through the rheostat, and the loss is just the same; it is lost in the rheostat itself,

and I know of no other way of avoiding that loss. The speed regulators are carried only as a handle of the rheostat. As the rheostat is turned from point to point we get the speed regulation between these points, and that is all. If we have 1200 revolutions and the next point gives 1000 and the next 800 there is no way of getting 900 or 1100.

Professor Benjamin.—I am not an electrical engineer, and I know very little about motors, or the eccentricities of their construction, but I know there are several firms who guarantee to be able to furnish a motor which will give the slow speed necessary for ironworking without any special loss. The Bullock Mfg. Co. has them, and I have seen the results of a test, which, if reliable, are very remarkable. The results were published in "Cassier's Magazine" about a year or two ago, and if they are correct the problem is solved.

Mr. Houghton.—I think the way most of the companies build motors for slow speed is to take, for instance, a 3 H. P. frame and put the extra winding on it, and in that way get a very slow speed. If you increase the size of the motor, you reduce the speed; motors can be placed on almost any machine, but where very slow speed is required they have to use a very large motor.

It might be interesting to know the price of operating motors. Last year the Illuminating Company had something like 1500 H. P. connected up, and the amount of money received showed the average cost per H. P. per month was $2.10 for operating a motor from the lines of the Cleveland Electric Illuminating Company.

Professor Benjamin.—For those who wish further information in regard to the Bullock Mfg. Co.'s machinery I would say that in one of the papers on the desk there is a cut of the Niles Tool Works, equipped with a Card motor.

STATE, CITY AND TOWN BOUNDARIES.

By Henry B. Wood, Member of the Boston Society of Civil Engineers.

[Read before the Society, April 25, 1898.*]

A boundary, in its original and strictest sense, is a visible object or mark indicating a limit, as of a territory; in practice, it may be a real or an imaginary limit, and hence may be indicated by visible marks or not, as the case may be. The state limit or boundary of land bordering on the sea is an imaginary line following the coast or high water line and one marine league therefrom, while individual ownership of such land extends only to extreme low water in this State, a stipulation made law by a special ordinance of 1647.

Natural streams or bodies of water are often used for boundaries between towns, the boundary line sometimes being the middle of the stream, the middle of the channel of the stream, and sometimes the high water line on the bank. In either case it is not always an easy matter to decide just where the line is located, as the stream is subject to change.

The old Province Laws recognized the importance of establishing the bounds of a colony, and made it obligatory on the officials to periodically view the markings, out of which grew the law relative to the powers and duties of towns, St. 1785, Chap. 75, and later as given in the Public Statutes, Chap. 27, which is as follows:

"Section 3. There shall be a perambulation of town lines, and they shall be run and the marks renewed once in every five years by two or more of the selectmen of each town, or by such substitutes as they in writing appoint for that purpose. After every such renewal the proceedings shall be recorded in the records of the respective towns.

"Section 4. Before a perambulation the selectmen of the most ancient of the contiguous towns shall give ten days' notice, in writing, to the selectmen of the adjoining town of the time and place of meeting for such perambulation; and selectmen who neglect to give such notice, or to attend either personally or by their substitutes, shall severally forfeit twenty dollars, to be recovered on complaint to the use of the county, or by action of tort to the use of the town whose selectmen perform their duty.

*Manuscript received November 15, 1898.—Secretary, Ass'n of Eng. Socs.

"Section 5. The selectmen of the contiguous towns shall erect, at the joint and equal expense of such towns, permanent monuments to designate their respective boundary lines at every angle thereof (except where such lines are bounded by the ocean or by some permanent stream of water), and wherever a highway crosses such lines. The monuments shall be of stone, well set in the ground, and at said angles, at least four feet high from its surface, and the initial letters of the respective names of such contiguous towns shall be plainly and legibly cut thereon; but it shall not be necessary to erect a new monument at said angles in a place where a permanent stone monument two feet in height above the surface of the ground already exists.

"Section 6. The selectmen of towns bordering on another state, where the lines between the states are settled and established, shall once in every five years give notice to the selectmen or other proper municipal officers of such towns in the other state as adjoin their towns of their intention to perambulate the lines between their adjoining towns. If such notice and proposal are accepted by the officers to whom they are made, a perambulation shall be made in the same manner as between towns in this Commonwealth. No boundary erected by authority of this Commonwealth and an adjoining state shall be removed by such selectmen or other municipal officers.

"Section 7. A selectman who refuses or neglects to perform any duty required of him by the two preceding sections shall forfeit twenty dollars."

The marks usually left under the regulations of the Province Laws were a stake and stones, or simply a pile of stones, or a tree or stump. Indefiniteness is a common fault. A portion of our own State lines—the Rhode Island line—is described by the commissioners appointed by that State to run out and mark the line in the following language, which illustrates the lack of permanency of the bounds:

CUMBERLAND LINE.

"We, the subscribers, appointed Commissioners by the General Assembly of the colony aforesaid to mark out the bounds of said colony eastward toward the Province of Massachusetts Bay, agreeable to His Majesty's royal determination in council, the 28th day of May, 1746, did, in pursuance thereof, on the second day of December last past, meet at Pawtucket Falls, in expectation of meeting with Commissioners that might be appointed by the Province of Massachusetts Bay, for the purpose aforesaid; and after having there tarried till the afterpart of said day, and no Commis-

sioners in behalf of the said Province appearing, we proceeded to run a due north line from Pawtucket Falls to the south boundary of the aforesaid Province of Massachusetts Bay, in manner following, viz. from a certain point on the southern side of Pawtucket Falls, where we erected a monument of stones, with a stake thereon, we run a meridian line, which directly passed through said falls, to a walnut tree on the northerly side of said falls; then to a pitch pine tree; then to a small white oak; then to a grey oak; then to a small bush; then to another small bush with stones about it; then to a heap of stones with a stake thereon; then to a black oak tree; then to another black oak; then to a small pitch pine; then to a black oak; then to a large white oak near the river called Abbot's Run; then to a poplar tree; then to a heap of stones with a stake thereon; then to a large rock with stones thereon; then to a small black oak tree; then to a walnut tree; then to a black oak; then to divers other marked trees in the said course, to the extremity of said line; and when we came near the termination of the said line, made a monument of stones, there being no noted south boundary of the said Province near the said line, and, therefore, for the discovery of the south boundary of the said Province, upon the best information we could obtain, proceeded to Wrentham Plain, at or near to a place where was formerly erected a stake called Woodward's and Saffery's stake, as one remarkable south boundary of the said Province, etc." * * *

One of our town lines—the Amherst-Granby line—is described as follows:

Corner No. 1.—Oak tree.
" No. 2.—Two walnut trees.
" No. 3.—Dead pine tree, stones around it.
" No. 4.—Black oak stump, 10 feet high, badly decayed, with stones around it.

The South Hadley line is described in part as follows:

Corner No. 6.—Two small hickory trees with stones.
" No. 11.—Treble hemlock on peak.
" No. 19.—Maple near birch stump.
" No. 20.—Black oak near dead pine.
" No. 23.—Black oak over the summit.
" No. 30.—Small maple in valley.
" No. 34.—Dead hemlock.
" No. 42.—Black oak west of dingle.

This line, originally defined by 51 similar "monuments," was straightened and re-marked in 1895 with 10 bounds of granite or iron.

Another description reads: "From a stake in the ice the line runs northerly 970 rods to a pine tree with a bird's nest and one egg in it" * * * * and another ends: "In the center of fourteen chestnut oaks on the side of Pine Mountain."

To provide against controversies likely to arise from an attempt to survey and mark boundaries of such fickle and indeterminate character, a law, as above quoted, was made compelling the selectmen of every town to faithfully attend to those duties.

It would seem to follow that each town or state line would be well marked and correctly so, and it would only remain to go to the town or state records to get a good description, and to provide for these locations by some of the modern methods of surveying that would admit of an accurate plot. But the law is not enforced and regular perambulations are not made in all cases.

STATE BOUNDARIES.

A recent paper read before the Boston Society of Civil Engineers by Mr. Frederick H. Newell, Chief Hydrographer of the U. S. Geological Survey, upon the hydrographic development of the United States, referred interestingly to the boundaries thereof, showing that the limits of the United States were first definitely laid down in the provisional treaty made with Great Britain in 1782, defining the boundary between the United States and the British possessions; 2d, the treaty of 1795, defining the boundary between the United States and the Spanish possessions, known as the Floridas. As it is well known, the northern boundary has been a bone of contention to the present time. It was extended along the forty-ninth parallel to the "Stony" (Rocky) Mountains in 1818, and a few years later to the Pacific, claims being made by contending parties as to territorial rights. The King of the Netherlands was selected in 1829 by both Governments as the arbiter, who made an award in 1831. Here for the first time the principle was established that the Government of the United States had not the power to change the boundaries of a state without the consent of the state, Maine being the first to enter a solemn protest, which was confirmed by the United States Senate; hence arbitration failed. Agreement was reached later with the consent of Maine.

Additions to the territory of the United States have been made from time to time, notably the Louisiana purchase from France in 1803, Florida from Spain in 1819, Texas being admitted as a state in 1845, the Mexican cession of 1848, including the Gadsden purchase of 1853, and Alaska in 1867, the consideration paid being

$7,200,000 in gold. The exact boundary of Alaska is a matter of great interest at the present time on account of the Klondike fever, one of the contested points being whether measurement shall be made back from the general shore line of islands or from the general shore line of the main land.

Of the thirteen original colonies, many possessed unoccupied territory west of the Appalachian Mountains, Massachusetts, among others, laying claim to areas in what was afterward known as the Territory Northwest of the River Ohio, a region now comprising Ohio, Indiana, Illinois, Michigan and Wisconsin. These claims being more or less conflicting and the boundary lines in most cases being ill defined, it was generally contested, especially by states having no such claims, that the resources of the General Government should not be taxed for the protection and development of this region to the benefit of a few. Following an act of Congress of 1779, the different states made cessions of this character, each transferring her territory to the General Government.

Massachusetts ceded an area west of a meridian line from the forty-ninth degree north latitude through the westerly bend of Lake Ontario, thence by said meridian line to the most southerly side line of the territory contained in the Massachusetts Charter, provided this line did not comprehend 20 miles west of the strait of Niagara.

The Massachusetts claim extended from the north line of the Connecticut claim northerly, and from the eastern boundary of New York to the Mississippi. It was ceded April 19, 1795.

The territory of Massachusetts was included in the first charter of Virginia, granted in 1606, and in the charter of New England, granted in 1620.

In 1628 the Council of Plymouth made a grant to the Governor and Company of Massachusetts Bay in New England, confirmed by the King and charter granted in 1629.

Extract:

"Nowe Knowe Yee, that Wee * * * have given and granted * * * all that Parte of Newe England in America which lyes and extends betweene a great River there commonlie called Monomack River, alias Merrimack River, and a certen other River there, called Charles River, being in the Bottome of a certen Bay there, comonlie called Massachusetts, alias Mattachusetts, alias Massatusetts Bay, and also all and singuler those Landes and Hereditament whatsoever, lying within the Space of Three Englishe Myles on the South Parte of the said River called Charles River, or of any or every Parte thereof. And also all and

singuler the Landes and Hereditaments whatsoever, lying and being within the space of Three Englishe Miles to the southward of the southermost Parte of the said Baye, called Massachusetts, alias Mattachusetts, alias Massatusetts Bay—and also those Lands and Hereditaments whatsoever, which lye and be within the Space of Three Englishe Myles to the Northward of the saide River, called Monomack, alias Merrymack, or to the Norward of any and every Parte thereof, and all Landes and Hereditaments whatsoever, lyeing within the Lymmits aforesaid, North and South, in Latitude and Bredth, and in Length and Longitude, of and within all the Bredth aforesaid, throughout the Mayne Landes there from the Atlantick and Westerne Sea and Ocean on the East Parte, to the South Sea on the West Parte."

This charter of New England was surrendered to the King in 1635 and a new charter was granted to Massachusetts Bay, which included Plymouth Colony and the Provinces of Maine and Nova Scotia. When Maine was admitted as an independent state, 1620, steps were taken to agree on its boundary, first settling the New Hampshire line, which took nine years. New Hampshire originally claimed jurisdiction as far west as the territory of Massachusetts and Connecticut extended, thus including the present State of Vermont, while New York at that time claimed all the country west of the Connecticut. A decree of the King in 1764 established the Connecticut River as the boundary line between New Hampshire and New York, which line became the boundary between New Hampshire and Vermont, as it is to-day. The above facts are gathered from Mr. Henry Gannett's sketches as recorded in the Geological Survey bulletins.

BOUNDARIES OF THE COMMONWEALTH.

1.—Massachusetts-New Hampshire-Vermont Line.

The controversy between the Provinces of New Hampshire and Massachusetts Bay (the commissioners being unable to agree) led to an appeal by New Hampshire to the King, who ordered the matter settled by a Board of Commissioners appointed from the neighboring colonies. Their decision of 1740 was as follows:

"That the northern boundary of the Province of Massachusetts be a similar curve line pursuing the course of the Merrimac River, at three miles distant, on the north side thereof, beginning at the Atlantic Ocean and ending at a point due north of Pawtucket Falls, and a straight line drawn from thence, due west, till it meets with His Majesty's other Governments."

George Mitchell and Richard Hazen were appointed by Mr. Belcher, then Governor of both provinces, to survey and mark the line, with orders to allow for a westerly variation of the needle of ten degrees. Mitchell ran the first portion and Hazen ran from the point north of Pawtucket Falls westerly. This was the recognized boundary line from 1741 to 1825. It was thought that Hazen's line ran too far north; at least it was so asserted by George Sproule (1774), who based his calculations on actual surveys and astronomical observations. The Massachusetts Commissioners contested this claim, on the ground that they were to mark the original line only.

In 1827 the original line was marked by suitable monuments, by order of the Legislature, and Borden's survey of 1830-8 was connected with them, which throws light on the true course of the Hazen line as marked by the commissioners of 1827. From 1827 to 1885 the Hazen line, as far as occupancy is concerned, has been the recognized jurisdictional line, although in theory the New Hampshire authorities have claimed the territory of about 60,000 acres, or about thirty towns, between that line and a due west line. From 1885 to the present time a special commission for Massachusetts has been endeavoring to co-operate with similar commissioners of New Hampshire and Vermont, and have monumented a line along the line of occupancy from corner to corner as found marked, with some variations from a straight line. This line, as marked, has been only partially ratified, a final report being nearly ready for submission to the respective Legislatures.

2.—*The Massachusetts-New York Boundary Line.*

The State of New York included the French and English grants of 1603 and 1606. The Dutch, in 1613, established trading posts along the Hudson River, and claimed jurisdiction over territory west of the Connecticut and east of the Delaware. In 1664 this territory was given by King George II of England to his brother, the Duke of York.

As stated in our Commissioner's Report for 1897, "The royal commission which had been sent out to visit various colonies in New England, and which had been given, among other duties, that of determining the boundaries between different colonies in disputed cases, declared the western boundary of Massachusetts to be a straight line twenty miles easterly from Hudson River and parallel with its general direction in this latitude. The location of the southerly end of the line appears to have been generally agreed to, but the direction of the line was the cause of much dispute.

"In 1767 the King referred the determination of the boundary to commissioners to be appointed by each province. In May, 1773, commissioners from both states met at Hartford, and after some discussion made a mutual indenture, stating that the line should be run from what was known as 'Connecticut Old Corner' parallel to the general course of Hudson River, which was agreed to be north 21° 10′ 30″ east. This was precisely the boundary which had been recommended by the King's commissioners ninety-nine years before. The above bearing had been determined by a survey of the river during the previous winter. The commissioners then started to run the line on the ground. After running by range poles about twenty miles the Massachusetts commissioners, finding that the line was bearing more to the east than it would if run by compass, owing to an increase in the variation of the magnetic needle as the survey proceeded northward, insisted that it should be run by compass from the beginning. This the New York commissioners would not agree to, and the dispute resulted in a suspension of the work.

"Nothing further was done until after the Revolution, when the dispute was brought to the attention of Congress; and a commission, consisting of Thomas Hutchins, Rev. John Ewing and David Rittenhouse, was appointed by Congress to run out and mark the boundary line between the State of Massachusetts on the east and the State of New York on the west. Thomas Hutchins was educated as a military engineer, and served as Geographer-General in the army under General Greene during the Revolution. Rev. John Ewing was vice-president of the American Philosophical Society, and a man of many scientific attainments. David Rittenhouse was a distinguished clock-maker and instrument-maker, and was employed, in addition to this work, in fixing the boundaries of Pennsylvania, New Jersey, New York and other states. The principal instrumental work of this survey was done by Mr. Rittenhouse. These commissioners began at the southerly end of the line, at what was then the southwest corner of Massachusetts, known as 'Connecticut Old Corner,' and ran a straight line north 15° 12′ 9″ east of the true meridian, in substantial accordance with the agreement made at Hartford in 1773, which stipulated that the line should proceed '21° 10′ 30″' eastward from the then magnetical meridian, the proper allowance for variation in magnetic declination being carefully determined and computed for the south and north ends of the line, and for the period of fourteen years elapsed since the time of the decree. The line ended at a red or black oak tree in the northerly boundary line of Massa-

chusetts, not found at the present time. The points were marked on the summits of hills crossed by stakes, around which were placed piles of stones and at occasional points by cuts in the ledges. Between these stakes on the summits lines were run by a good compass, and other stakes with piles of stones were placed at each mile point, counting from the southerly end. No other marks were placed on this line by the commissioners, but at various times since then stone bounds and other marks to identify town and property lines have been placed by local authorities and by surveyors on what they considered to be the boundary line." (See report of Topographical Survey.)

In 1853 a small area of about 1000 acres in the southwestern corner of the State, and west of the mountain summits, was ceded to New York by Chapter 340 of the acts of that year. This section was known as "Boston Corner," and was given to New York to insure proper police protection against prize fights and other acts of lawlessness not easily regulated by the authorities on the east side of the mountains on account of inaccessibility.

Thus the line has remained until the year 1887, when, under the authority of the New York State Engineer and Surveyor, the Wilson survey was made. This survey was established by assuming a few points at the southern end of the line, about two and a half to five miles apart, the monument at "Boston Corner," a mark that appeared to be the "Crow's Foot" cut at Alander, and points on Cedar and Prospect Mountains, as the best authentic evidence of the direction of the line, and then translating this short line northerly in the direction thus determined. The result was that the stone piles which were found were mostly on the easterly side of this base line, and varied in offset from a few feet in the southern portion to 108 feet at the northern end of the line. An opinion was given that only ten of the points found were really the original markings, and that all the stone piles between the eighth mile-post and the forty-first mile-post were very uncertain, and were mostly local. This survey was done wholly at the expense of the State of New York. The line was not chained.

The Massachusetts authorities were invited to join in remarking the line at that time, but, having no act of legislature to legalize such a proceeding, they were compelled to decline.

In 1897, however, the Massachusetts Legislature authorized the Topographical Survey Commission to co-operate with the officers or agents of the State of New York to locate, define and mark the true line, and a survey was undertaken. Taking advantage of the data and information previously gathered together and

carefully reported, it was thought best to lay out as the base line of the present survey a line which would more nearly correspond to the average location of the stone piles which had been found. This would naturally lead to the discovery of other stone piles not previously found, and the cutting over such a line could be done at less expense than in the thick young growth that now covers the location of the Wilson line. Furthermore, as Mr. Wilson had reported that Alander Mountain and Mount Misery, 38¼ miles apart, were intervisible, and as Berlin Mountain was recorded 200 feet higher in elevation than Mount Misery, it was thought probable that two points on the original line could be selected, one at Alander Mountain and the other on Berlin Mountain, which would be intervisible and enable us to establish a longer straight line base from which intermediate points on summits could be lined in exactly with a straight line instrument. The woods on the second knob of Mount Misery prevented our using Berlin, and Mount Misery was finally selected.

The instrument used was a Straight Line Transit (No. 90), made by Buff & Berger. The aperture is two inches, magnifying power forty diameters. The lenses were made by Clark, of Cambridge. It has three leveling screws, and can be accurately centered by a motion of the base. The height of one of the Y's is adjustable. The cross-hairs are of the X pattern, and are quite fine. It is provided with a delicate striding level. The axis is of hardened bell metal. The top of the tripod is very broad, and gives great steadiness. This instrument was originally designed for alignment of the tunnel under Dorchester Bay, in the construction of the Boston Main Drainage system. Heliotropes were used for signals.

Alignment of Base Line.

Alander was selected as the instrument station, as the light was favorable in sighting northerly.

With Buff and Berger special straight line transit No. 90 located at Alander, and set upon the flash at Mount Misery for a foresight, the flash at Mount Harvey was set on line eight times, approaching from opposite sides alternately, and the telescope being reversed in the Y's each time and adjusted with a striding level. The four points from the east were within a space of 1¾ inches, and the four points from the west were set within a space of 2 inches, while the distance between the two extreme points of both sides was only 6¼ inches, causing the means to fall within the space of 9-16 of an inch. This long sight from Alander to Misery was 38¼ miles.

As samples of transiting and alignment other than the one at Mount Harvey, above mentioned, the following may be cited:

With transit No. 90 on Alander Mountain, using the staff on Mount Prospect for a backsight, a group of east and west points was obtained by transiting and setting a target 2 feet square at "Boston Corner." The groups of sightings were 13½ inches apart, and fell within a space of 2 11-16 inches and 1 11-16 inches respectively; and their average fell 13.75 inches east of the marble monument at "Boston Corner," set by Simeon Borden. The distances were: Prospect to Alander, 4¼ miles; "Boston Corner" to Alander, 2½ miles.

With transit No. 90 at Mount Fray, on the eighth mile point, a foresight on Mount Harvey, or the nineteenth mile point, the 2-foot target was set eight times on the fifteenth mile point at Hillsdale, all within a space of 5⅝ inches.

With the instrument at Mount Harvey (the nineteenth mile) and the heliotrope at Mount Misery (thirty-eighth and one-quarter mile), points were set at Cunningham's Hill, Perry's Peak, the thirty-second mile point, and on Round's Mountain, all with good results.

All of the points north of Mount Misery to the end of the line, covering about 13 miles, were set by transiting the line ahead. The triangulation controlling the line shows these points to be exactly on line, no azimuth as taken from the inverse computations of a common origin showing a greater variation than one-tenth of one second.

In all of the above work the best time of day for observing was found to be after four o'clock P.M., except, of course, on cloudy days.

As the base line of survey was proved to be a thoroughly straight line by subsequent primary triangulation which was brought to bear on it, its location with reference to the old stone piles and other marks left by the commissioners of 1787, as far as they could be identified, is the chief consideration for determining the boundary line to be adopted. About twenty-five marble monuments and over seventy stone piles were discovered, some on the line and some either east or west of it.

The offsets of prominent marks recovered are as follows:

Alander (crow's foot or arrow), 1.9 feet west of line.

Prospect (cut in ledge), 1.8 feet east of line.

Harvey (old stone pile), 0.7 feet west of line.

Marble monument (Richmond and Hancock corner), 0.0 feet.

Marble monument (Lebanon and Pittsfield road), 2.0 feet west of line.

Marble monument (Goodrich Hollow road), 3.0 feet east of line.

Marble monument (Shaker Village road), 1.65 feet west of line.

Mount Misery (stone pile transit post), 5.4 feet west of line.

Rhode's Pinnacle (stone pile transit post), 0.0.

Berlin Mountain (stone pile transit post), 8.0 feet east of line.

From a review of the offsets but one conclusion can be drawn, —viz, that this base line of survey is a good average of the 1787 points now recoverable on the ground, and therefore represents as well as may be the original boundary intended to be laid out. It will without doubt become the adopted boundary between the two states, and will be marked by suitable monuments.*

3.—The Massachusetts-Connecticut Line.

This line was settled by commissioners in 1713, but their contract being declared void on account of its not being approved by the King, no final agreement was reached till 1803, when the portion from the west bank of the Connecticut River to the northwest corner of Connecticut was both surveyed and marked. These marks are not all preserved. The portion from the Rhode Island corner to the east bank of the Connecticut was surveyed and marked in 1826. Most of these monuments can be found at the present time. Their condition will be a subject of investigation in 1898.

4.—The Massachusetts-Rhode Island Boundary Line.

Gannett says: "This line was for more than two hundred years a question of dispute, and was in some respects the most remarkable boundary case with which this country has had to do. Twice in the Supreme Court, and once with Daniel Webster and Rufus Choate as counsel for Massachusetts. As early as 1642 the line between the two colonies was marked in part by Nathaniel Woodward and Solomon Saffrey, who set up on the plains of Wrentham a stake as the commencement of the line between Massachusetts and Rhode Island. This stake was supposed by them to mark a point 3 miles south of the Charles River."

In 1880 and 1881 the northern boundary of Rhode Island was settled, after a continuous controversy since 1849, by marking a

*Since the above was written, this line has been agreed upon by the authorities of the states, and it is being marked by large granite bounds 12 inches square and 9 feet in length at all highways and summits, and 5 foot bounds at each mile point, substituting cast iron posts set in cement concrete at inaccessible points.

jurisdictional line having the same termini as the line of 1848, but irregular, sometimes running north and sometimes south of it, the extreme variations being 529 feet north and 129 feet south. This line was well monumented, and an excellent plan filed in the State archives.

The easterly boundary line from "Burnt Swamp" corner to "Peaked Rock," at the Atlantic Ocean, was the dividing line between Plymouth Colony and Providence Plantations, and was almost constantly in dispute from its original establishment to 1861. Various attempts were made to settle it by commissioners appointed by the two states, and a settlement was finally agreed to by the commissioners in 1848. Their decision was ratified by the Legislature of Rhode Island, but not by the Legislature of Massachusetts. Suit was afterwards brought in the United States Supreme Court to settle the line, and in 1861 a decree was entered, with the assent of both states, establishing the line. A portion of the line fixed by this decree consists of a portion of the extreme high water lines on the westerly sides of South Watuppa and Sawdy Ponds, in Fall River, and the stream connecting them, and a portion of the extreme high water lines on the easterly banks of what are known as Seven Mile and Ten Mile Rivers, on the easterly side of the city of Pawtucket.

As many of the bounds marking the line were either lost or never set, and others were from 400 to 1000 feet distant from their true location, a readjustment of the line was desirable to be followed by marking the exact location on the ground in a plain and definite manner.

By Chapter 88 of the Resolves of 1897 the Topographical Survey Commissioners were authorized and directed, acting with any officer or agent appointed by the State of Rhode Island for a like purpose, to locate, define and mark a series of straight lines along the jurisdictional line between Massachusetts and Rhode Island, from the "Burnt Swamp" corner in Wrentham southerly to the sea, following as near as may be the line established by decree of the United States Supreme Court in 1861.

A complete reconnoissance of the line was first made and the survey followed, made by a joint party representing both states. The work was laid out on three distinct lines,—viz, triangulation, base line, or traverse work, and topography. Traverses were run, depending for accuracy upon the checks furnished by the triangulation. Existing monuments were located, and the topography developed where high water boundaries made it necessary. A full description of the survey may be found in the report of the Massachusetts Topographical Survey Commission for 1897.

The errors in chaining were only about 1 in 8000, and, as all important angles were covered and controlled by a system of triangulation direct from strong Coast Survey bases, there can be no uncertainty as to the accuracy of the results. It is intended to substitute for high water lines a series of straight lines, following as closely as may be the original boundary, and so laid out that the exchange of territory between the two states shall be equal. This will be followed by resetting all old monuments found to be off the line, and the establishment of new corners marked by granite monuments, 12 inches square and 9.5 feet long, set 4 feet out of ground. About 150 points in the whole 50 miles will thus be remarked, and the line, left in good condition, will doubtless be ratified by the Legislatures of both states.

5.—*Town Boundaries.*

The importance of an accurate determination of the boundary lines of towns was made very apparent to the Massachusetts Commissioners during the first year of the topographical survey of the State begun in 1884 in co-operation with the U. S. Geological Survey. They found many boundary lines of towns described in vague and misleading terms, distances erroneously stated, corners omitted, a common line between two towns recorded and described in conflicting terms in the records of the two towns, and in many cases no record. In fact, it was common knowledge that the records were wrong or incomplete, and that the lines were located, if located at all, by very crude and imperfect methods. The commissioners plainly stated that "a good topographical map, upon which the locations of town lines are accurately shown, would be a great auxiliary in identifying the positions of the various points and angles; but the determination of the lines should not be an incident in that survey, or depend upon the plottings of the map, but should, on the contrary, be effected with such precision as to be a basis for the survey itself, and form a framework, as it were, to which all other surveys within its limits could be referred."

Yet the topographical survey, as authorized, could not be extended to include so large and expensive a feature as the determination of town boundaries, although its necessity was fully set forth as follows:

"The system of determining town lines by triangulation was a part of Mr. Simeon Borden's masterly scheme of the State survey, devised fifty years ago, and was partially carried out and several points in the State boundary line were included in his triangulation,

but the determination of town boundaries was not practically carried out. Such a plan would give to the State Government, and to each municipality in it, a perfect record of the exact boundary of each city and town in the Commonwealth, and in so methodical and precise a manner that any city or town engineer or ordinary land surveyors could reproduce the exact position of any point in any line. The system of record should be uniform with that of the other geographical positions determined by the triangulation of the State survey, giving the latitude and longitude of each point, probably within one or two feet of its true position; whereas, as now described, many angles and even whole lines are probably out of position hundreds of yards, and in some places hundreds of rods."

That the information at hand was meagre is shown in their original estimate of the work involved. There were at that time 347 towns and cities in the Commonwealth, and the total number of points or angles in the boundary lines of all of them was reported as about 1700, while there have been located to date about 2500 corners, and the State is less than half done. In many towns that appeared to have from four to seven corners, we have found from twenty-five to thirty. Some towns have as many as seventy-five corners. The commissioners early confessed that they were unable to make a satisfactory estimate of the number of points in the boundary lines to be determined. The appeal to the Legislature for funds with which to undertake this work as a special survey led to a beginning of the work in 1885, and by successive appropriations from year to year it has been in progress until the present time. The first year's work brought to light the magnitude of the undertaking somewhat, and called forth a retraction of preliminary statements as to its probable cost and the time it would take to complete it, and, at the same time, a decided stand was made as to the feasibility of its accomplishment and the usefulness of its results.

The scheme of location has been to use, when possible, as a base line, some triangle side as determined by the U. S. Coast and Geodetic Survey or one established by the Massachusetts Corps of Engineers by extension of their work, and develop a secondary system of triangles to points at or near the corners themselves; in the latter case, to connect with the corner by a short traverse line or by measuring a small base with a tape establishing a small quadrilateral connection. (See Conn. River Triangulation.)

It was soon found, as the work progressed inland, that the larger triangulation, upon which the work is based, would have to

be extended, especially toward the interior and western section of the State, owing to a loss of the exact positions of certain of the triangulation stations of the earlier surveys, and also to discrepancies which arose when the work of the Borden triangulation of 1831 was compared with the more accurate work of the Coast Survey. The Borden system was not as strong in the western part of the State as it was farther east, and it grew more and more difficult to recover some of the markings of the stations. The primary work has, therefore, been extended to the western boundary of the State, recovering as many of the Borden points and the U. S. Coast Survey stations as possible, and thus making the scheme of primary basis of equal strength throughout the State, and leaving the points permanently marked. The results are now being computed in Washington at the Coast Survey Office, and will give us ample control of all western towns. These observations were made with a repeating theodolite belonging to the U. S. Coast Survey, with an 8-inch circle reading to five seconds. Long lines from twenty to sixty-six miles required the use of heliotropes, usually of the form commonly adopted by the Coast Survey and Army Engineers. An improvised and rougher form has been used to good advantage, being made at small expense and easy of manipulation, as described by the assistant in one of the annual reports.

The results of this primary triangulation have been very satisfactory, giving points of control within reasonable distance of one another, whose geographical positions may be computed to the required limit of precision and verified by checks incident to the method. The probable error in this work is from $\frac{1}{20000}$ to $\frac{1}{30000}$ in distance, the observed angles varying in series not over two seconds and often agreed within a second, the instrument reading to five seconds.

On taking up a new section, where the primary work has been completed, the officer in charge first provides himself with all the information that can be obtained from the archives of the State relative to the laws establishing the town lines and then obtains from the selectmen of the towns concerned copies of their latest perambulations, and confers with the selectmen in regard to them. After getting all the information obtainable the field parties go on to the ground, and perambulate one town at a time, finding successively every corner. They then ascertain, by reconnoissance of hills nearest the boundary points, what known stations or available sites for new ones will command the respective corners of boundary points, and erect signals to a proper height, say from 8 to 100 feet. The shorter signals are usually built directly on the

monument. Where a signal has to be from 50 to 100 feet high, in consequence of wooded ground, tall straight young trees are cut and spliced together. Three wire guys are then made fast to the signal pole at each place where it is spliced. A fall and block is made fast to the signal and to some suitable tree near it, and the signal is raised into place. A white band just below the flag placed at the top is then plumbed carefully over the center point of the bound and held in place by a set of guys. Observations are then made with a transit or theodolite, in sets of six angles each, forward and backward, varying the number of sets according to the size of the triangles, the least number of sets being from four to six.

Topographical sketches of town bounds are made, based on instrumental work, traverse lines being run as nearly as possible on true azimuth, to show how the point may be reached from the nearest roadway, and the necessary topographical features are located by stadia readings for distance, and the elevation of the more important points determined by means of vertical angles. This work requires the services of but two men besides the observer at the instrument.

As the boundary survey progresses the imperfect condition of the perambulation returns, and the fact of the disregard by many of the selectmen of the law in regard to marking and erecting bound marks and monuments becomes more apparent.

The commissioners' report shows that during the season of 1895, out of 151 boundary points determined, it became necessary to have 81 bounds at "corners" set under the surpervision of the field party, which were improperly marked or not marked at all.

Where the mountain ranges form the boundaries between a number of the towns, the lines following "the highest part of the mountain," it would be a very expensive and arduous task to get stone monuments of sufficient size to the summits. In such cases iron posts have been substituted. These posts consist of 2-inch iron pipes 4 feet in length, firmly fastened to the out crop of ledge and surmounted by a cast iron cap 6 inches wide, on the opposite sides of which are cast the letters of the respective towns between which the post forms a bound. The posts and caps are painted white, with the exception of the letters, which are black, and are easily distinguishable through the trees in wooded places for long distances.

ROAD STONES.

The boundary survey to the present time has been made to include all "corners" so called, *i.e.* bounds at well-defined angles. Perambulations showing angles of less than 2 or 3 degrees have

been disregarded and road stones are usually supposed to be on line. A survey and examination of the road and line stones, as they exist, was made in a few test cases, and they were found to vary from a straight line between the corners from a few feet to a hundred feet or more on one side of the other of an intended straight line. The legal value and importance of these marks seemed to call for legal opinion. The commission have, therefore, recently referred the matter to the Attorney-General, and his reply contains the following statements:

"Town boundaries can be fixed only by statute. No agreements between towns or their officers by perambulation or otherwise are effectual to alter or vary lines established by statute.

"It often happens, however, that the statutes defining town boundaries, especially the older ones, are uncertain or ambiguous. It may also happen that the line is described in general terms, and that reference must be had to facts existing at the time of the enactment of the statute to ascertain the intention of the Legislature.

"In all cases where the statute is ambiguous or uncertain, recourse may be had to other evidence for ascertaining the true line intended by the Legislature. The principal evidence so resorted to is that afforded by perambulations and bound stones or monuments. * * * * * * * * *

"Neither these perambulations nor the bound stones so provided to be erected can control or alter the bounds between towns as fixed by statute. Com. v. Heffron, 102 Mass. 151. But in cases where the true boundary is uncertain, or the words of the statute fixing the boundaries between towns is ambiguous, such perambulations and bound stones may be resorted to as evidence of the true boundary." * * * * * * *

From this opinion it seems that line stones and road stones are of greater importance than they have been formerly regarded.

Chapter 336, of the acts of 1888, was framed to provide for the definition and preservation of town boundary lines, and provides that the Commission on Topographical Survey may propose changes by straightening or otherwise in existing boundary lines, to be ratified by the Legislature, after acceptance by the towns interested. It also provides for the re-marking of angles and corners in such a manner as to establish a uniform system, as indicated by the commissioners, and makes it unlawful for any person to remove, obliterate or cover up any monument or mark so made.

Under this act several very crooked lines have been straightened and improved, reducing the number of angles to a very large degree. On one line four straight lines replaced twenty-six

courses without materially affecting the extent of territory in each town.

A whole estate in Concord is entirely surrounded by territory that belongs to Carlisle, and the boundary near by follows the irregular outline of adjoining farms.

A Boxford boundary appearing to require six or eight lines has over thirty-eight courses in the old description, varying from one to four degrees in bearing.

Many other cases could be cited to show the necessity of the straightening lines when local conditions seem to require it.

RESULTS.

Out of 353 towns and cities in the Commonwealth, 225 appear by the reports to have been wholly or partly surveyed to date, as far as the main field observations are concerned. As the personnel of the commission has changed from time to time, and the development of the work has constantly thrown new light on the condition of the lines, it is found that both the nature, extent and standard of the work required or ordered by the commission has varied; so that as the time has come for publication, all these varying conditions must, of necessity, be reduced to a uniform basis; omissions must be supplied, etc., and every fact bearing on each boundary line fully considered and weighted. Hence, in nearly all of these towns some one or more items of information have yet to be supplied, involving in many cases some slight additional field work.

Proof sheets of the new atlases are now being revised and a few towns will be published during the coming year, and the publication will be pushed as rapidly as possible, after the standard has been fully established.

A revision of the topographical atlas sheets of the Metropolitan district is contemplated by the U. S. Geological Survey in cooperation with our State Survey, and the points determined in our town boundary survey will be utilized as points of control for this adjustment. The field work for this season has already been approved and provided for.

The following authorities are recorded as connected with town boundary work of Massachusetts:

Supervisor, the late Prof. Henry L. Whiting.

Triangulation—by the United States Coast and Geodetic Survey, United States Geological Survey, Simeon Borden, Gershom Bradford, F. W. Perkins, Henry F. Walling, C. H. Van Orden, James B. Tolley, Eugene E. Peirce, E. G. Chamberlain, W. C. Hawley.

The last six gentlemen have executed the secondary and town boundary work proper. The present commissioners in charge are: Desmond FitzGerald, chairman; Prof. A. E. Burton, Frank W. Hodgdon.

General Walker summed up his opinion of town boundary work as follows:

"We believe it may be truthfully asserted that the completion of the contemplated work of determining the boundary lines of the cities and towns of Massachusetts in a manner commensurate with the scientific and accurate standard of the trigonometrical surveys already made at large cost to the State and to the United States, and which for the want of some such supplementary application to practical uses have been thus far of little value to the Commonwealth, will be the beginning and form the best basis for a cadastral (property line) survey of a state yet provided in this country."

WOODEN STAVE PIPE VS. RIVETED PIPE.

By D. C. Henny, Member Technical Society of the Pacific Coast.

[Read before the Society, November 4, 1898.*]

In enterprises requiring the use of pressure pipe, the selection of the kind of pipe to be used under the various conditions of pressure, diameter, cost of material, freight rates and accessibility constitutes one of the most difficult problems to be solved by the engineer.

To reach intelligent conclusions it is desirable that the knowledge resulting from experience be the main guide, and a discussion of the comparative merits of different classes of pipe, based upon existing works, may to some extent assist in the proper solution of this problem.

The object of this paper is to compare the two classes of pipe mentioned in the title; and, as the advantages of riveted pipe, owing to its more extended use, may be supposed to be more generally known, it is the intention more in particular to set forth the merits of stave pipe.

Instead of treating this subject in a general way, it is proposed to use a special piece of work as a basis of comparison, because this method offers the advantage of directness and concentration, while the principles involved are none the less of general application. For such common basis it is necessary to select some work or project that is generally known and that does not put either class of pipe, particularly the better known riveted pipe, at a disadvantage. In this respect the main pipe line of the Coolgardie Goldfields Water Supply is conspicuous, since the project as a whole has attracted much attention owing to its unusual magnitude, and since the chief engineer and consulting engineers united in recommending the use of riveted steel pipe (with some reservation).

For a detailed description, reference is made to the reports of Mr. C. Y. O'Connor, chief engineer, and of the Commission of Engineers consisting of Messrs. Deacon, Carruthers and Unwin; further to the editorial descriptions in *Engineering News* of February 10, February 17 and October 13, 1898.

In general, the proposition is to build a storage reservoir near

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the coast, where rainfall is sufficiently heavy, and to convey the water through a pipe line 328 miles in length to Coolgardie. The point of delivery being 1313 feet vertically above the source, a series of pumping stations was planned and so arranged as to pump the water to some high point beyond each station and cause it to flow by gravity to the next station beyond.

The capacity of the entire work was fixed at 6,000,000 U. S. gallons per day, delivered at Coolgardie, and the economical diameter of the pipe was determined to be generally 30 inches, except that a few sections were made $28\frac{1}{2}$ inches, $27\frac{1}{2}$ inches and 24 inches. The frictional resistance in the 30-inch pipe for the above-mentioned flow was placed at 3.103 feet per mile, the velocity being 1.888 feet per second.

The magnitude of the entire project and the relative importance of its component parts are best shown by the chief engineer's estimate:

Pumping engines and sheds	$1,000,000
Main pipe line	9,150,000
Reservoirs	1,500,000
Distributing mains	850,000
Total	$12,500,000

The scheme itself involves no new principles and is simply a multiplication of the more common arrangement of a single pumping plant and pipe line; yet, in view of its enormous cost and the peculiar climatic conditions, the Government of the Colony appointed a Commission of Engineers to report upon the material and method of manufacture of pipes, their diameter and strength and the method of protecting them, the position of the several pumping stations, the desirability and size of intermediate reservoirs and such other subjects as would result in the highest possible economy and the greatest certainty of success.

The commission performed its work with the thoroughness and skill that might have been expected from the large experience and high standing of its members. It is to be regretted, however, that, as it was essential that all improvements in recent design and practice should be fully considered, one or more American experts were not added to this board. Climatic and social conditions in Western Australia bear a much closer resemblance to those in the Western United States than to those in England, and, as these conditions are often the economical causes of striking differences in engineering practice, American experts would undoubtedly have been able to offer suggestions of the greatest value.

With the foregoing estimates before us, the great responsibility placed upon the consulting engineers can be readily understood, and they have been undoubtedly governed by a desire to combine a proper measure of conservatism with utilization of the most economical methods for conveying water under pressure. In doing so, they have considered straight and spiral riveted steel and iron pipe, so-called Ferguson's pipe,—a steel plate pipe with rivetless dovetailed longitudinal joint (see *Engineering News*, June 9, 1898),—and welded steel pipe.

Wooden stave pipe does not appear to have been considered by the commission, and the reasons for this are not entirely clear, but no doubt they have their origin in the fact that this class of pipe has so far been used neither in England nor in any of its Colonies except to some extent in Canada.

As stated before, the commission, in its "Interim Report," recommended the use of straight riveted steel pipe, although some further investigations were to be carried on with reference to the Ferguson pipe. As it is believed that, besides a large amount of riveted steel pipe, some 80 miles of Ferguson pipe have now been contracted for by the Colony, it may be presumed that these investigations were highly satisfactory, the more so because, so far as present information on the subject discloses, only about 8 miles of this pipe have heretofore been built.

It should be further stated that the commission recommended that the steel pipe be laid above ground to avoid contact with the soil, said to be strongly impregnated with alkali; that it be built in solid sections a little over one hundred feet in length anchored in the middle and resting on proper supports, and that these sections be united by expansion joints permitting the required amount of axial motion.

Having thus explained the basis upon which comparison is to be made, the author proposes to consider whether wooden stave pipe might be viewed as suitable and safe for conditions and projects similar to that described, and, if so, whether it would offer any advantages over the use of riveted pipe. The questions which present themselves in such a comparison are those respecting leakage, limiting pressure, life, carrying capacity and cost.

Leakage. This is mentioned first because of its exceptional prominence in a pipe line 328 miles in length. So far as anticipated losses from a wooden stave pipe are concerned, they may be due to two causes,—leakage proper and evaporation from its surface when exposed. For the estimation of either, measurements of

actual losses from existing pipe lines alone will give the needful information. To the writer's knowledge, there are three pipe lines upon which measurements have been made to determine the actual losses from wooden stave pipe. The first was a buried 18-inch pipe in Astoria, Oregon, in regard to which the following is stated by Mr. A. L. Adams, in his paper on the "Astoria Water Works" (Trans. Am. Soc. C. E., Vol. XXXVI., page 20).

"A test for tightness was made of the upper $2\frac{1}{2}$ miles of this pipe line after the water was first turned in. This gave results which the author believes have never been surpassed by any other pipe construction of any class. The pipe was filled from the head works, and, the gate at the lower end of the section being closed, the water rose and passed off through the overflow from the stand pipe immediately adjoining the gate. The head gate was afterwards closed. This gate was not absolutely tight, but permitted the passage of a little trickling stream, not exceeding perhaps one quart in a minute. The assistant engineer in charge of the works was much surprised on the following day to observe this same little trickling stream, apparently undiminished in quantity, passing through the waste pipe at the end of the line."

The second pipe line mentioned consists of 4.3 miles of 14-inch pipe near Los Angeles, a section of the pipe line supplying the National Soldiers' Home with water. The pipe is buried, the cover being generally 24 inches in depth. At each end of the section a concrete manhole, with cross wall and steel plate weir, permitted the measurement of the flow by means of carefully placed hook gauges; the weirs, the cross walls and the gauges being as nearly alike as possible. Three successive experiments were made, also by Mr. Adams, with flows gradually reduced in order to increase the relative importance of the leakage, in the last experiment the flow being at the rate of about 32,000 gallons per day. The first two measurements showed a slight excess of flow at the lower end over that of the upper end, probably resulting from unavoidable differences in the finish of the weir plates. In the last experiment the flow measured at both ends was, as nearly as could be measured, the same, showing the pipe to be absolutely tight. The pressure in the Astoria pipe ranged from 0 to 80 feet, the thickness of the Douglas fir staves being $1\frac{3}{8}$ inches. In the Soldiers' Home pipe the pressure varied from 0 to 65 feet, and the thickness of the redwood staves was $1\frac{1}{8}$ inches.

The third experiment mentioned was made by the author and

included the combined losses from leakage proper and from evaporation under unusually severe conditions.

A 52-inch wooden stave pipe, 968 feet in length, was built to carry the water of the Santa Ana Canal across Deep Canyon, near Redlands, California. (Trans. Am. Soc., Vol. XXXIII.; Hall, on Santa Ana Canal.) (See Photograph.) The pipe has the form of a U, with the sides inclined instead of vertical. The connecting curve has a radius of 300 feet, with its lowest point subject to a water pressure of 165 feet, and is supported by a wooden trestle 50 feet high in the middle. The pipe rests on sills, both on the mountain sides and on the trestle, and is therefore entirely exposed to the hot and dry climate of Southern California. The staves are of redwood, the finished thickness being 2 inches for pressures less than 50 feet, 2.3 inches for pressures from 50 to 100 feet, and the remainder 2.6 inches.

When, upon completion early in July, 1893, it became apparent that it would be a question of months before water could be let into the pipe through the flume, it was decided to fill the pipe by pumping in order to avoid the possibly injurious lengthwise shrinkage, after completion, of the staves, which were not thoroughly dry when put in. At the lowest point connection was accordingly made with a one-inch pipe leading up from a small pump below, which drew its supply from the creek in the canyon. Pumping continued until the creek finally dried up, the pipe being then filled to within 25 feet vertical of the ends.

The trestle, which supports only a portion of the bottom curve, had settled perceptibly as the pipe filled, and it continued to settle for some time, as was apparent from the buckling of the feed pipe, which had to be twice cut and shortened. The effect on the pipe of this settlement was that, as the pipe off the trestle could not follow the downward movement, severe longitudinal strains were induced, which were further aggravated by the breaking of some of the sills under the pipe on the trestle. These strains manifested themselves by the slight opening of the butt joints, many of which commenced to drip. Attempts were made to stop these leaks, but, so long as settling continued, leaks would persistently reappear either where stopped before or at new points. Settlement finally ceased and all leaks were permanently stopped, but this was not until after the end of the experiment. The surface of the water in the pipe, as it gradually lowered, was measured from time to time, with the following results:

Length of pipe filled in feet.	Average length of pipe filled in feet.	Length of pipe emptied in feet.	Time in hours.	LOSS U. S. gallons.	U. S. gallons per day.	U. S. gallons per day per sq. foot exterior surface.	Average pressure at bottom in feet during experiment.
800	757.5	85	231	9384	975	0.086	132
715	708.5	12.9	57	1419	597	0.057	123
702.1	692 5	19.2	93	2120	547	0.053	120
682.9							

It was impracticable to determine separately the losses from dripping leaks and from evaporation, although it may be assumed that a large portion of the loss, as last measured, was due to evaporation both from the water surface at the open ends and from the surface of the pipe. There would be nothing surprising in this, considering the prevailing temperature of the air and of the stagnant water in the pipe, the permanent sunshine throughout the day and the frequent hot winds blowing up or down the canyon.

While it is admitted that the results are not conclusive, they point to the probability of losses from evaporation, that may become serious in very long pipe lines exposed from end to end. So far as they go, the measurements may be valuable as establishing a maximum value for all losses under conditions as described.

Whether asphalt or paint can be made to adhere to the outside of the pipe, and whether a coating would materially reduce the losses from evaporation, are subjects in regard to which there exists difference of opinion among engineers, and which cannot be settled except by trial. The author knows of only one line of pipe that is exposed and coated on the outside, and when he had occasion to examine it, after about four years' service, he found the asphalt coating in bad condition and practically offering no protection at all. Whether this was because the coating was driven off by the water pressure, or because the asphaltum had not been of the proper consistency, he had no means of determining, but he is inclined to believe that the first-mentioned cause is liable to prevent firm adherence and effective protection.

The exterior surface of 328 miles of 30-inch pipe would, in round numbers, amount to 15,000,000 square feet, and, if the daily evaporation from its surface should reach 0.05 gallons per square foot, the entire daily loss would be 750,000 gallons; on the other hand, the first two experiments mentioned indicate that the loss from a buried wooden pipe, even if 328 miles in length, would be very small, provided it be well designed and carefully constructed.

Measurements of the loss from riveted steel pipe have not come to the author's knowledge, nor is it stated in the report of the commission how the estimate of 5 per cent., or 300,000 gallons

Examples of Wooden Stave Pipe.

Location	Name	Length	Buried	Diam.	Thickness	Wood	Head
Astoria, Oregon	Astoria W. W.	$2\frac{1}{2}$ mi.+?	yes	18"	$1\frac{3}{8}$"	fir	80'
Los Angeles, Cal.	Natl. Sold. Home	4.3 mi.	[illegible]	14"	$1\frac{1}{8}$"	redwd.	65'
Redlands, "	Santa Ana Canal	968'	no	52"	2.6"	"	165'
					2.3"	"	100'
					2.0"	"	50'

per day, which includes losses from the intermediate reservoirs, has been arrived at. Why it has been expressed in percentage of total flow is not clear, as there is no connection between the velocity and the leakage.

One of the arguments in favor of laying the pipe on the surface was that leakage could be more readily found. This may be true in the case of very open, gravelly soils, but in ordinary ground it has been the author's experience that even exceedingly small leaks will make themselves apparent if the pipe is buried at ordinary depths, which is in part borne out by the records of the Astoria and Los Angeles pipes mentioned.

Limiting Pressure. The pressure which wooden stave pipe can be made to withstand safely depends upon the hardness of the saturated wood, and a working pressure of 200 feet is considered by the author and shown by experience to be a safe practical limit in the case of redwood and Douglas fir, for reasons which it is beyond the scope of the present paper to discuss. If the staves are carefully selected, there will be no loss from percolation through the wood at the highest pressure when the pipe is buried.

The Coolgardie line, as now located, contains 255 miles, or about 80 per cent. of the total, on which the maximum pressure is 200 feet or less. These pressures are based on the grade lines as determined and laid down by the commission for steel pipe. The lightest gauge to be used is intended for pressures from 0 to 220 feet (for 30-inch pipe), and there was therefore no object in so locating the pipe as to reduce the pressure within these limits, which explains why, with a few exceptions, the location of the line simply parallels the railroad from Fremantle to Coolgardie. Easy accessibility, especially in an uninhabited country, is unquestionably a great advantage, but is not essential, and when stave pipe is under consideration it is customary to be governed, in making location, by the comparative cost per foot of pipe under various pressures. The practical result is generally an economical compromise between an excessively long contour line and a straight line, with heavy pressures. Such a course leads to increased length for the sake of economy, and, in a case like that at Coolgardie, it would also have the effect of greatly reducing the amount of pipe upon which the pressure would exceed the limitation set for stave pipe construction.

As to steel riveted pipe, the safe limit of pressure under which it can be built is undoubtedly much higher than the highest pressure on the Coolgardie line.

The commission recommended that the strength of the pipe be determined from hydrostatic pressure, with the exception of the section between the second and third pumping stations. This recommendation was based on the ground that the advantages of stop valves at regular intervals along the line were considered so great as to outweigh the great extra cost involved in making the pipe strong enough to stand the full head of water when at rest in the main. The section between the second and third pumping stations, excepted by the commission from this general recommendation, has been left subject to pressures from hydraulic grade only. This was done because the method followed for the other sections would have increased the already high pressures, some 200 feet, on about 36 miles of pipe, and it was therefore recommended that a reservoir be built at one of the intermediate summits. No reason was given why, since any small reservoir, basin or even stand pipe, placed at hydraulic grade just upstream from a main gate, will give relief and protection against increase of pressure over that due to hydraulic grade, this method was not followed on the other sections at least in part. With such overflows placed at every point where the pipe line approaches hydraulic grade, even assuming the distance between such points to exceed the desired standard distance between main gates, the pipe line would be divided up into sections, the maximum pressure upon which would be measured by the elevation below that of the nearest overflow upstream. It cannot be believed that the temporary waste of water at the points of overflow would present any serious obstacle. Moreover, it may be presumed that a telephone line will parallel the pipe line, so that it will be generally possible, if so desired, to have the pumps at the head of the section stopped before any gate is closed.

This matter is touched upon here because, with stave pipe, the close relation between cost and pressure renders any inexpensive method of reducing even moderate pressures highly desirable, and it is for this reason that most wooden stave pipe lines now in use have been carefully protected from unnecessary pressures. In case waste of water cannot be tolerated, the same object can in part be attained by the construction, at each summit, of a small basin into which the pipe discharges through a balanced valve operated by a drum float. The section of pipe down stream from this basin cannot be subjected to any pressure greater than that due to the depth below high water in the basin, for, even should the balanced gate fail to act, the basin would then overflow. This simple and inexpensive arrangement reduces the maximum pressure by steps,

and has been successfully applied to the 14-inch wooden stave pipe near Los Angeles already quoted.

Life. At the outset it will be necessary to distinguish the two cases of pipe buried and pipe exposed. When exposed, the steel bands of a stave pipe can be constantly inspected and repainted whenever deemed necessary, and the life of this portion of the pipe may be considered sufficiently long to satisfy all requirements. As to the staves, it must be evident that changes of temperature and wind will cause a steady movement back and forth of the limit of saturation within the staves, thus leaving the outer skin of the wood in a condition where it would eventually decay. This decay need not necessarily result in the loosening of the bands, as the wood under the bands would be protected from evaporation; yet it would finally reach a depth where there is a permanent saturation, with a consequent steady increase of the losses from evaporation. Uncertainty as to the effect of a coating of asphalt or paint applies to this subject as well as to that of losses from evaporation.

There are short trunk lines for power purposes in the New England States, which, though built of pine, exposed, and, moreover, at times running but partly full, have seen from 20 to 40 years of service and are still in use, and from sound redwood better results might be expected. The general practice, however, is to bury the pipe, except where, owing to rocky formation or necessity of placing pipe on a trestle or bridge, such course is impracticable, and then the pipe has generally been boxed in.

When buried, the conditions determining the life of the stave pipe are reversed. Supposing the pipe to be filled at all times,—a vital condition to be strictly adhered to,—the staves will remain permanently water-soaked for their full thickness and no decay can take place. But the steel bolts and iron couplings will then be in contact with the soil; nor will it be practicable to re-coat them. Hence the endurance of the pipe will then be measured by that of the metal, and will be, to a great extent, dependent upon the protective coating and the character of the soil. On this important subject experience has not been sufficiently long to warrant any definite estimate, and only general conclusions can be drawn. It is important in this connection to disabuse the mind from considering the life of steel pipe as in any way furnishing evidence on this point, for the cases are by no means parallel. The life of an iron or steel pipe is not limited by any consideration of weakened strength resulting from corrosion, but rather by the peculiar pitting action to which the plates are subject. The result is that leaks occur in some places, while at others the plate is yet perfect, and

the constant recurrence of leaks finally forces abandonment of the pipe when the actual percentage of metal lost by corrosion is very small. Were it practicable to line with wooden staves the inside of a completely worn out metal pipe, a serviceable pipe would be obtained, promising long life, and the steel would not be strained up to its limit of strength until about 75 per cent. of the metal had rusted away. This is the condition of the wooden pipe, with the important exception that the metal on the outside of the pipe does not occur in a form exposing a relatively very large surface to corrosive influences as with plate; but, on the contrary, in a condensed form, the round section of the bolt presenting a minimum of surface to contact with the soil.

A forcible illustration of this difference was furnished on a compound wooden and riveted steel pipe line built in the spring of 1896, for the Hollister (California) Water Company. In the fall of 1897 a portion of the steel pipe, after having required an ever-increasing expense for repairing leakage through pit holes in the plate (No. 14 B. W. G.) had to be replaced, and, as this portion was near a point of junction of wooden and steel pipe, and the pressure presented no obstacle, it was decided to extend the wooden pipe and connect with the steel pipe beyond where the trouble occurred. The soil in which the wooden and the steel pipe had been buried was adobe, and, so far as could be judged, was identical for both kinds of pipe. The corrosion of the steel pipe seemed to have proceeded mainly from the outside, and it therefore became a matter of interest to note the condition of the steel bands on the wooden pipe. It was found that the asphalt coating had deteriorated, but the metal under it showed hardly any sign of corrosion, and the nuts could easily be turned on the threads. Other portions of the steel pipe (some of it No. 12 gauge) have since been replaced by cast iron pipe; while, on the contrary, the wooden pipe is, so far as known, in practically the same condition as when first laid.

The oldest continuous stave pipe of any magnitude was built by Mr. J. T. Fanning, in 1874, for the Manchester, N. H., Water Works. (See Trans. Am. Soc., March, 1877.) The pipe is 72 inches in diameter, banded with $\frac{1}{2}$ x $2\frac{1}{2}$-inch flat iron hoops and is buried. It has been in constant use, has required no repairs and is stated to be in good condition so far as known.

After carefully weighing all evidence on both sides of this question, the author concludes that, even assuming the presence of alkali in the soil, a longer life is insured—supposing the bands

to be thoroughly coated—when the wooden pipe is buried than when left exposed.

As to riveted pipe, it is, as a rule, buried; the only exceptions which occur to the author being where the pipe had to be frequently moved, as in hydraulic mining and dredging, and occasional short stretches, where special conditions intervene. The life of buried steel pipe is very uncertain. In many cases even light gauge pipe has lasted remarkably well; in others it has had to be abandoned in a very short time, as in the case of Hollister above cited.

Of numerous instances, one more may be quoted, showing the short life of light steel pipe laid in alkali soil. Echo Lake and West Lake, forming part of the irrigation system of the city of Los Angeles, are connected by pressure pipe. Originally a 20-inch No. 16 B. W. G. steel pipe was used, about one mile of which had to be abandoned at the end of three years, after considerable expense had been incurred in stopping leaks, which were all the more annoying because of the pipe's location near the center of the city. A No. 14 B. W. G. steel pipe was then laid, which lasted four years, and in the spring of 1895 was replaced by wooden stave pipe.

The lightest gauge for the Coolgardie steel pipe recommended by the experts is 3-16 inch, and, as previously stated, it is proposed to lay this pipe on the surface in order to lessen the danger from corrosion and to facilitate the detection of leaks. A double asphalt coating is specified, all of which may fairly be expected to insure long life for the pipe proper. While the gain in the life of the pipe, in being kept from contact with the soil, cannot be questioned, it may be asked whether this is not too dearly paid for by the necessity of providing and maintaining an enormous number of expansion joints, unless indeed some type of joint can be devised which does not depend for its tightness on rubber or other elastic material promising but a short life under severe climatic conditions and which can be repacked without interrupting the flow in the pipe.

It is interesting to note here that the much discussed question of comparative endurance of steel and iron is disposed of by the commission with the statement that they see no reason for preferring one to the other.

Carrying Capacity. It is to be regretted that the number of experiments for the determination of the carrying capacity of wooden stave pipe are as yet very limited. The following is believed to contain all direct knowledge on the subject:

EXPERIMENTS ON FLOW THROUGH WOODEN STAVE PIPE.

Authority.	Locality.	Year.	Diameter in Inches.	Length in Feet.	Fall per 1000.	Observed Velocity Feet per Sec.	Coefficient "C" Chezy Formula.	Coefficient "n" Kutter Formula.
Adams	Los Angeles	1898	14.11	4403	.145	.691	105	.0106
			14.075	3436	.161	.695	101	.0109
			14 05	4825	.170	.698	99	0111
			14.05	8931	.178	.751	104	.0108
			14.05	9912	.391	1.167	109	.0107
			14.05	8931	.375	1.181	113	.0105
			14.05	9912	.638	1.53	112	.0108
Adams	Astoria	1896	18	23,318	1.9628	3.605	133	.0099
Schuyler	Denver	1891	30	....	....	....	....	.0096
Marx, Wing and Hoskins	Ogden	1897	72.50	2710	.0952	1.242	104	.0148
				2710	.181	1.876	114	.0139
				2710	.331	2.689	120	0134
				2710	.517	3.453	124	.0131

It may be said in addition that some measurements were made in 1892 by the author to determine values for "C" and "n" on a line of 24-inch stave pipe at Butte, Mont., 18,389 feet in length, that for a velocity of 1.147 feet per second the value of "C" was found to be 127, corresponding to a value for "n" of 0.0103, but that he hesitates to attach great weight to this result, as the only method at hand to determine the flow was from frequent determination of velocity by means of vertical floats in a semicircular flume at the upper end of the pipe. This method was liable to considerable error.

The author has generally made use of the Kutter formula for computing the capacity of wooden stave pipe. He was led thereto by the consideration that experiments on new cast iron pipe show this formula to give fairly constant values for "n" under greatly varying conditions of flow and diameter, and that wooden stave pipe offers, in this respect, a nearer resemblance to new cast iron than any other kind of pipe on which a wide range of measurements is available, although it may be assumed to have a smoother interior surface. The value of "n" applicable to new cast iron pipe was found to be 0.011, 48-inch pipe being the largest size experimented on. The variations from this value are irregular and seem to point rather to probable differences in surface finish and errors in measurement than to incorrectness of the formula itself.

For wooden pipe the author assumed a value for "n" = 0.010,

because in open channels, lined with smooth planed boards, smaller values had been found, and because this assumption has been corroborated by experiments on 30-inch pipe made in Denver, Col. (Trans. Am. Soc. C. E., Vol. XXXI.) It is further confirmed by the experiment at Butte on 24-inch made in 1892, and again by the Astoria experiments on 18-inch pipe made in 1896.

The Ogden experiments were made last year and the results are unquestionably unexpected. It is beyond the scope of this paper to consider in detail whether some unusual conditions did not exist which may have contributed to the results, and it is sincerely hoped that the experimenters will still further put the profession under obligation by carrying out their intention to extend the range of their experiments and thus throw further light upon this subject.

The latest experiments on wooden stave pipe were made on a 14-inch pipe at Los Angeles by Mr. A. L. Adams. As will be noted from the table, they are with rather low velocities and give values for "n" between 0.0105 and 0.0111.

From the foregoing the author concludes that for diameters from 24 to 30 inches a value of 0.010 for "n" may be fairly expected. He wishes to emphasize, however, that from a commercial point of view it seems essential at times to provide a reasonable margin of safety in estimating the required diameter of a pipe line; for instance, where delivery of a stipulated quantity of water is contracted for and where the attainment of even a slightly smaller flow might entail serious consequences, or, as in a case like that of Coolgardie, where the pipe line interlocks with expensive machinery designed to pump and give greatest efficiency for a certain predetermined flow. Should this flow not be attained there would be clearly waste in first cost of pumps and possibly also in subsequent cost of pumping. Hence in such cases the size of the pipe should be based upon what it is reasonably certain to carry, rather than upon what it may carry, and, in using a value of "n" = .011 for 30-inch wooden pipe with low velocities, as in Coolgardie, it is believed that an ample but not excessive margin of safety is provided. From this a value of "C" = 128 would result and a frictional resistance of 1.838 feet per mile. A most important fact in this connection is that, so far as known, the interior surface of wooden stave pipe does not become rougher with age. The author has heard the possibility advanced of a vegetable growth starting on the interior surface of the pipe, which would impede the flow, but, so far as known, no such growth has yet been observed in pipes after many years of service. Nor has the author ever heard of any

growth in the interior of bored wooden pipe, of which hundreds of miles have been in use. He has been informed of roots growing into a wooden pipe, but that was under conditions where the vital requirement that it be kept full of water had not been observed, but where, on the contrary, the pipe had never run full, and where originally careless construction and insufficient back-cinching had permitted the wood to shrink and the seam joints to open. Such growth had not been from the interior, but had penetrated from the outside through the open top seams, in search of moisture, as has been often similarly noticed in open jointed drain and sewer pipe.

It is believed that experience does not warrant any apprehension in this direction, but rather that it indicates that wooden pipe, if properly used, will retain its original carrying capacity for an indefinite time.

The experiments on new riveted steel pipe now available tend to show that the Kutter formula does not apply to such pipe. The more simple Chezy formula, however, gives fairly satisfactory results, at least for velocities of $2\frac{1}{2}$ feet per second and higher, when the value of "C" can be uniformly taken at 110. For lower velocities the value of "C" ranges within rather wide limits. While for a velocity of 1.5 feet per second the value of "C" in the 72-inch Ogden pipe was 111, it was found to be 91 in the 36-inch pipe of the East Jersey Water Company, and, for the same velocity, intermediate values have been found for intermediate sizes.

The foregoing refers to new pipe only. Experiments with pipe which has been in use several years show a decided decrease of capacity. For instance, a 48-inch pipe of the East Jersey Water Company gave a value of "C" = 106 when new, and = 85 when four years old, for 1.5 feet per second velocity. For practically the same velocity the value of "C" in the 36-inch pipe at Rochester, when 14 years old, was found to be 80, and, for a velocity of 3.3 feet per second, the 24-inch pipe at Rochester, of equal size, gave a value of "C" = 78.

The Commission of Engineers, in estimating the required diameter for the Coolgardie steel pipe, placed the value of "C" at 98. In the light of the above-mentioned experiments it seems doubtful whether sufficient allowance has been made for probable deterioration by tuberculation. If it be conceded that in the course of time the value of "C" may fall below 98, the desired flow of 6,000,000 gallons daily can no longer be maintained even by increasing the pumping pressure, as the pump mains proper constitute but the first and smaller portion of each section of pipe be-

tween stations, the remainder being gravity pipe laid with summits near hydraulic grade.

Assuming, for the values of "C", for 30-inch stave pipe, 128, as deduced above, and for 30-inch riveted pipe, 98, as adopted by the commission for the Coolgardie main, the respective frictional losses for a velocity of 1.888 feet per second would be 1.838 feet and 3.103 feet per mile, a difference of 1.265 feet per mile in favor of wood or 415 feet for a line 328 miles in length. The total pumping head, in the case of Coolgardie, was stated to be 2605 feet, and a decrease of 415 feet would mean a reduction equal to 16 per cent. In justice to riveted pipe it should be stated that the above comparison would hold good only in case the wooden pipe were buried by reason of the necessity of providing for losses from evaporation, which would materially change the results. For independent reasons elsewhere stated, the author believes, however, that wooden pipe should be buried whenever possible.

Cost. Considerations of effect of pressure on cost, limiting pressure and differences in frictional losses make it essential that location should be made with special reference to the kind of pipe to be considered. It would obviously lead to erroneous results to make the location best suited to one kind of pipe the basis for an estimate of another kind of pipe.

In order to bring out the economical possibilities of wooden stave pipe it may be stated that the author finds that under conditions as regards freight rates, etc., similar to those stated in the chief engineer's report as applying to the Coolgardie main pipe line, the cost of 30-inch redwood stave pipe, laid and buried, may be estimated at $1.70 per foot for pressures less than 20 feet, increasing gradually with the pressure to $3.90 per foot for 200 feet pressure. The cost of the steel pipe was estimated by the chief engineer at $5.29 throughout for all sizes and weights and inclusive of fixtures.

What would be the resulting economy in the use of wooden stave pipe for a portion or all of a pipe line like that at Coolgardie is a question upon which the author, for the reasons given, does not wish to venture. It may be stated, however, that while it is true that a stave pipe location generally shows a greater length of line than that for steel pipe, such additional length would result from economical consideration only, and would be the cause of a reduction rather than an increase of total cost.

In a case where water is to be pumped, the cost of main pipe line is not the only point to be considered. If, owing to lesser friction in stave pipe, the total pumping head be reduced, a reduc-

tion in the first cost of pumping machinery would result, and a corresponding reduction would follow in the annual cost of pumping, which, in the Coolgardie case, is estimated by the chief engineer at over half a million dollars. Should, in a similar case, a saving of 16 per cent. in these items result, as was estimated, it is evident that there might be substantial economy in the use of stave pipe, even at a greater cost per foot than riveted pipe.

DISCUSSION.

Mr. Allardt.—In Honolulu we have an insect called the bumblebee, that bores into the wood in houses, making holes almost as large as my thumb. Would a wooden pipe be subject to such attack by the bumblebee or other insects or vermin? Is there any danger of a rodent working into a pipe in search of water, say a ground squirrel or gopher?

Mr. Stut.—Some time ago I met Mr. Henny on the Oakland boat, and we were comparing steel and wooden pipe, and discussing the question as to which would last the longer, and I put the question as to why steel pipe should be used in place of iron pipe, when the former was eaten out so quickly. My idea is, in the case of steel, that it is eaten away by the action of electrolysis. Now, in steel the presence of two elements, iron and carbon, is favorable to galvanic action. Inside of the pipe we have water, and on the outside we have alkali. We know that if iron and carbon be dipped in water, or in any saline solution, an electric current will be formed, and this will affect the steel; we get an electro-chemical element that goes on day and night, and in a very short time the steel is eaten up. With iron, which is practically free of carbon, this will not be the case. In Australia, if the pipe were buried in the ground, I think iron rather than steel should be used.

If I place in water a small piece of carbon and a small piece of iron, a current of electricity will be formed; the current will go from one to the other and the material will be eaten up. As to the eating away of steel pipe, I think this is the only true explanation that will hold good. I have had a good deal of experience in sugar factories. In one we have an iron tank about 16 feet high and 5 feet in diameter. As the sugar is melted it runs through bone coal. The inside of the tank is painted with the best kind of metal paint. The iron is apparently well protected, but in a very short time the solution of the sugar gets behind the paint and eats the iron. In handling coated pipe, the coating gets knocked away or cut into in places, which are thus left open to attack.

Chairman Marx.—Such a coating would not be protective.

Mr. Stut.—Only to a certain extent. Some years ago, in a sugar factory, we had a large pan lined inside with big copper coils, into which steam was turned to drive the vapor off from the sugar. There was a fixed cast iron arm and pipes connected with the pan, and a clamp was used to hold them in position. The clamp broke, and, not having anything else, a big copper wire was used to perform the service of the clamp. When we next opened the pan, we found the copper had a large groove in it as though it had been cut with a saw. That was the result of electric action. The combination made a sort of galvanic battery.

Mr. Allardt.—If the iron or steel pipe is in a trench in alkali soil, but the pipe is surrounded with a layer of sand, and this sand becomes wet, either from leakage of the pipe or from rain, will the alkali on the outside extend to the pipe and produce this electric action?

Mr. Stut.—It would, no doubt, in the case of steel. With iron there would be less trouble. I should always use iron in preference. In the case of wooden pipe there is the wood, and the steel hoops around the wood, and the steel would not come in contact with the water inside the pipe. That would be different from the case where the entire pipe was of iron or steel, which has water on one side and the alkali on the other. It is well known that the slightest current must produce chemical action.

Mr. Norboe.—In regard to the bumblebee that Mr. Allardt mentioned, I presume most of you are aware that we have a bumblebee in California that bores into wood. I have seen cedar so honeycombed by them that it looked a good deal like a pile eaten by the teredo.

The question why steel should be used in preference to iron in pipes is to some extent a matter of cost. The pipes are calculated to resist a certain pressure, and the greater tensile strength of the steel is certainly a factor in causing its selection over iron; because, to resist the same pressure, we should require much heavier material, and the extra cost of transportation would also cut quite a figure.

I have never had much actual experience with wooden pipe, but I have investigated it pretty thoroughly, and I believe that in many places where it is not now used it can be used with greater economy than any other material.

Mr. Hoskins.—Mr. Henny has certainly made a plausible showing in favor of most of the points he has brought forward in regard to wooden pipe. I cannot quite agree to all he says upon

the question of capacity. Upon this question his reasoning does not appear to be altogether safe when applied to pipes of large sizes.

The amount of evidence available regarding the carrying capacity of wooden pipes is very small indeed. Experiments have been made upon a 14-inch and an 18-inch pipe, both apparently fairly reliable; also with a 24-inch pipe, admitted to be of uncertain value; and with a 30-inch pipe, regarding which data are lacking from which to judge of the accurary of the results. Then there are the experiments upon the 72-inch pipe at Ogden. These are the only ones to which I have found any reference.

The only published reference to the experiment on the 30-inch pipe is contained in the paper by Mr. Schuyler, in the Transactions of the American Society of Civil Engineers, and it is there treated in two or three sentences. It is stated that the discharge was determined by two methods,—by measuring the depth added to the reservoir in a given time, and by measuring the velocity with a current meter at a manhole in a tunnel. As a result it was found safe to use the Kutter formula with "n" = 0.010. Upon this brief statement it appears unsafe to attach much weight to this test, in the entire absence of corroborative evidence regarding pipes above 18 inches in diameter.

In order to bring out clearly the nature and value of the evidence now available regarding the capacity of stave pipe, it is instructive to consider the growth of our knowledge regarding the capacity of riveted steel and iron pipes. At present there is a considerable amount of experimental knowledge regarding the capacity of riveted pipes. But experiments on the larger sizes came much later than on smaller sizes, and it was found wholly unsafe to apply to pipes upwards of 3 feet in diameter the values of the Kutter coefficient found for smaller ones. My colleagues and myself, in the paper describing the Ogden experiments, have tabulated all data known to us regarding the capacity of riveted pipes. Of the experiments on pipes smaller than 36 inches in diameter, nine (diameters ranging from 11 inches to 35 inches) gave "n" equal to 0.010 or 0.011, while not a single experiment on a pipe which was new or probably as smooth as when new gave a value of "n" greater than 0.011. If no experiments had been made on pipes of larger size, doubtless many engineers would advocate the use of Kutter's formula for riveted pipes of all sizes up to 48 inches, or even 72 inches, with "n" = 0.011 for all sizes. That such a procedure would be wholly unsafe is shown by the fact that experiments on new riveted pipes of diameters from 36 inches to 72

inches have in nine cases given values of "n" ranging, for average velocities, from 0.013 to 0.014, while in no case has a less value been found. It would seem that there is at least a possibility that those engineers who assume that Kutter's formula, with "n" = 0.010, may safely be applied to wooden pipes of all sizes are erring in somewhat the same way in which many erred in the case of large riveted pipe before reliable experimental data regarding the larger sizes had been made public.

I have thus far said nothing in regard to the results given by the Ogden experiments. Mr. A. L. Adams, in his paper before the American Society of Civil Engineers (September, 1898), has disregarded those results because they did not agree with the results found for pipes of smaller sizes on the basis of Kutter's formula. Without desiring to magnify the importance of the Ogden results, I may express the opinion that experiments on pipes 14 inches, 18 inches and 30 inches in diameter, however reliable, can furnish no justification for the rejection of an experiment on a 72-inch pipe. To do this because Kutter's formula requires it seems to me to give undue authority to that formula. It surely cannot be assumed, apart from experimental knowledge, that Kutter's formula is applicable to wooden pipes of all sizes; yet here the formula is appealed to as the sole justification for rejecting a series of experiments on a pipe of diameter more than double that of any other whose capacity has been measured.

The Ogden experiments do not stand alone in discrediting Kutter's formula as a safe guide in the design of large pipes when accurate knowledge of the discharging capacity is required. The coefficient "n," which is assumed to depend only upon the nature of the surface, has been found to vary both with the diameter and with the velocity of flow. The variation with velocity has been pointed out by several writers. In the Ogden experiments on the steel pipe "n" was found to increase with increasing velocity, while in case of the wooden pipe "n" decreased with increasing velocity. In the experiments with the 14-inch stave pipe at Los Angeles, Mr. Adams found "n" greater than 0.010, but in the few gaugings made (all at low velocities), a tendency was observed for "n" to decrease as the velocity increased, and it was only by assuming such a change in "n" that these tests were brought into conformity with the Astoria test on 18-inch pipe.

The question of capacity is not the governing element in all cases, but in many cases it is important. The difference between the capacity as estimated by Kutter's formula with "n" = 0.010 and that indicated by the Ogden results is so great as to materially

influence the design when the capacity needs to be carefully considered. The "C" in the Chezy formula, for 72-inch pipe, assuming the Kutter coefficient to have the value used by Mr. Adams and Mr. Henny, would equal about 163 for a velocity of 3 or 4 feet per second, while the value found in the Ogden experiments for similar velocities was about 125. The difference between these values is very material indeed.

In estimating the weight to be given to the Ogden results as a guide to future design, it should be noticed that the pipe experimented upon was curved for a considerable part of its length, and that this curvature doubtless influenced the loss of head. How great this influence would be we have no means of estimating. But if the curvature of the pipe is an important element affecting our results, it is also important in most practical cases, and should receive far more attention than is usually accorded to it in estimates of carrying capacity. I do not think the curves in the Ogden pipe are exceptionally sharp in comparison with what is usually considered allowable.

The riveted pipe experiments quoted by Mr. Henny are mostly for low velocities, in accordance with his special basis of comparison. It should be borne in mind that the probable error in a value of "C" determined from an experiment is great in proportion as the velocity is small. Judging from our experience at Ogden, where our velocities ranged from 0.5 feet per second to about 3.8 feet per second, I should be inclined to give little weight to a single determination of "C" at a velocity less than about 1.5 feet per second. Of course by multiplying the number of observations a reliable mean result may be reached for a velocity as low as 1 foot per second.

Mr. Allardt.—It seems to me that as to the relative discharging capacity of wooden stave pipe and steel pipe, we must decide in favor of the wooden pipe, from the fact that it has a smooth inner surface, while steel pipe has a rough surface on account of the rivets and laps. So the discharge of a wooden pipe of the same diameter must necessarily be greater than that of a riveted pipe.

Mr. Marx.—That question has not been raised. There is no doubt in the minds of Mr. Henny and Mr. Hoskins that the carrying capacity of a wooden stave pipe is larger than that of riveted pipe of the same diameter. It is simply a question of whether or not the Kutter formula, with "n" = 0.010, can be safely applied in calculating the carrying capacity of wooden pipe—whether there has been sufficient experiment to prove it. Mr. Hoskins and some others take issue on this point.

Mr. Henny.—The question of rodents injuring stave pipe has been frequently raised. The stave pipe supplying Butte, Montana, passes through ground honeycombed in places by prairie dogs, which, however, have never disturbed it. There are a great many gophers around Denver, where stave pipe has been buried for fifteen years, and we have yet to hear of a gopher having eaten into the pipe. They do not seem to like it.

As to ants, we had some experience in Los Angeles. Staves were piled up along the line. In one place they were laid in brush on the hillside, and there it was observed, when pipe building commenced, that ants had eaten into the staves, making small holes never over $\frac{3}{8}$ inch in depth. The ants were always found in pairs in these holes and may have bored in to deposit their eggs. That portion of the line has been carefully watched, but no further evidence of their existence has been discovered. A number of these ants were laid before Dr. Behr, of the Academy of Science, who pronounced them to belong to the same family as the white ant of Central America. He said similar ants had attacked wooden sidewalks in this city. It is the author's belief that while they may eat into dry or partly dry wood, they will not attack wood that is thoroughly saturated. If they require air for life, they cannot live in a saturated stave. In the Santa Ana pipe, which is exposed, the wood may dry out possibly a quarter of an inch at times, and an ant or a bumblebee might eat into it to that depth, but at night the moisture would come to the outside. So it is not likely their work would be injurious. No attack from bumblebees or ants has so far been observed in either the three lines of 52-inch pipe of the Bear Valley Irrigation Co., which have now been in over 3 years, or an older 48-inch pipe, which has been in 8 years, all exposed.

In regard to the particular point Mr. Allardt has raised as to the comparative carrying capacity of wooden and steel pipe, my recollection is that, so far as the Ogden experiments are concerned, the value of "C," instead of being 163, was 125 or a little higher, while in steel pipe of the same diameter it was 110. Those experiments gave the wooden pipe about 13 per cent. the advantage.

In answer to what Mr. Hoskins has said in regard to the Ogden experiments affecting the applicability of the Kutter formula to stave pipe, it may be here repeated that the author's use of the Kutter formula was based not so much on the few experiments on stave pipe, but rather on the fairly satisfactory results obtained with new cast iron pipe, and the similarity in character of interior surface was noted so far as absence of rivet heads, laps or other obstructions are concerned, with the stave pipe

having the advantage in point of smoothness. When practically the same value of "n" is found for a 6-inch as for a 48-inch new cast iron pipe, for a fair range of velocities, without startling differences for intermediate diameters, it may be concluded that the Kutter formula is applicable to new cast iron pipe, and, by inference, to other pipes with unobstructed section, within the range of the experiments. Beyond this range estimation becomes necessarily to some extent speculation, until further information be obtained, such as the Ogden experiments. Then, if this new information differ greatly from what was inferred from previous knowledge, it is closely scrutinized and the weight to be accorded it must remain a matter of personal judgment. The Ogden experiments would incline the author to greater conservatism in estimating the capacity of large stave pipes.

Darcy's experiments, with semicircular channels running full, are considered by the author to throw some valuable side light on the question, especially those with channels of large diameter. A channel 49.2 inches in diameter, lined with pure cement, gave a value for "n" = 0.0102; another, lined with mortar containing two-thirds cement and one-third fine sand, gave "n" = 0.0109, and another, 54.1 inches in diameter, lined with partly planed boards, gave "n" = 0.0118. In all these cases the depth of water equaled the radius, the values for "n" practically remaining the same for all depths.

As well-planed wood compares favorably with pure cement in smoothness, the Darcy experiment, first quoted, seems to confirm the inference that a value of "n" = 0.010 may be used for wooden stave pipe up to diameters of 48 inches, leaving out of consideration additional friction that may be caused by short bends or great percentage of sweeping curvature.

The latter will in some way have to be estimated (or, as the case now stands, guessed at) separately.

It is very desirable that the range of the Ogden experiments be extended. So far as they have gone, the trend is towards an increase of the value of "n" as the velocities increase. Additional experiments are bound to throw further light upon this subject, and, in a measure, to be a check upon the data now at hand.

Mr. Marx.—I will state, for the information of Mr. Henny and the members of the Society, that, since these experiments were made at Ogden, a temporary dam has been built which raises the level of the river some ten feet. It will therefore be possible to extend the range of experiments to velocities higher than those previously experimented on by us, and arrangements have already been made for doing so.

Mr. Hoskins.—Mr. Henny has referred to experiments on semicircular open conduits as bearing on the question of capacity. It has been assumed by writers on hydraulics that circular conduits flowing half full have the same values of "C" and of "n" as when flowing full, the hydraulic radius having the same value in the two cases. But this has been regarded only as a rough approximation, which is used in the absence of better knowledge. In some respects the semicircular section resembles the circular, and in other respects they are not the same. The assumption that the influence of the form of the cross-section upon the rate of discharge is wholly accounted for in the value of the hydraulic radius is a deduction from a theory acknowledged to be defective, and is not borne out by such experimental knowledge as we have, except in a very rough way. We have very little definite knowledge regarding the distribution of velocity throughout a cross-section.

The Kutter formula is an ambitious formula. It was designed by its inventors to apply to open channels of all sizes and forms. As used by certain writers, it is still more ambitious, assuming to give a rule for computing the discharge of any stream from a half-inch pipe up to the Mississippi River or the Amazon. The experiments upon which it is based justify us in accepting it as a good formula for certain classes of channels,—good because no better means of estimating discharge are available, but not to be expected to give results of great accuracy. But the experimental basis does not include much in the way of pipes above the smaller sizes, and it would be strange indeed if the formula, with a constant value of "n" for all diameters, should give very accurate results upon large pipes. Of the data available, I think the majority is rather against the formula than in its favor, for pipes above 3 feet in diameter. This is certainly true of riveted pipes, as I have already shown. It is asserted that experiments on smooth conduits show closer agreement with the formula; but for pipes of large sizes I think the evidence is too limited to warrant such a conclusion. The experiments of Fitzgerald on 48-inch smooth cast iron pipe agree well with the formula, showing a nearly constant value of "n," with varying velocity. But the only other experiment upon a smooth cast iron pipe as large as 4 feet in diameter which I have seen recorded gives a much smaller capacity than was found by Fitzgerald and by Stearns. Of the available data much is of uncertain value. In many cases probably a high degree of accuracy in the measurements was not attempted. The methods of measurement employed have not always been such as to insure results of a high degree of reliability. A weir will not give

good results unless constructed and used with the greatest care. A reservoir measurement is liable to errors due to evaporation and leakage, in addition to observational errors, which can be eliminated only by the greatest care. The majority of the available data are based upon measurements made by these methods, and in many cases it is uncertain whether proper precautions have been observed.

In view of these facts and of all the evidence, I think we are justified in questioning the applicability of Kutter's formula to circular pipes, with a constant value of "n" for a given kind of surface.

PROF. WING.—To obtain results we have to rely upon experimental data, and we have to use such formula as will best apply to those experiments. It makes but little difference what formula we use, so long as we do not use it outside the range of experiments. We must depend upon experiments for determining our coefficients of friction. Then we can adopt any formula that will apply to the range of experiments. Outside of this it is not safe to use any formula.

MR. HENNY.—I wish to correct a statement that has been made in regard to the Kutter formula. It is in no way based upon experiments made upon pipes. I do not know that Gauguillet and Kutter themselves advocate it for use on pipes, as none but experiments on open channels were used for a basis. Later, the formula was tested for pipe, and, so far as pipe with unobstructed interior is concerned, it was found to give better results than any other formula.

Mr. Hoskins questions the weight of the experiments made on semicircular open conduits, as applied to pipes. It seems to the author that the hydraulic differences between a half circle running full, and a full circle of the same diameter running full, are very small, much smaller than between deep and shallow open channel sections of various forms, to which the Kutter formula is conceded to apply, and that the experiments made by Mr. Darcy on semicircular conduits have a direct bearing on the full circular conduit, and are moreover in line with experiments on new cast iron pipe.

Considering the time and expense involved in making experiments of this character, it is not to be wondered at that individual engineers can so rarely follow their inclinations in this direction, and it is therefore all the more gratifying to learn that the experimenters on the Ogden pipe have made preparations to continue and extend the work commenced last year. The results will undoubtedly be awaited with the greatest interest.

Editors reprinting articles from this journal are requested to credit both the JOURNAL and the Society before which such articles were read.

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ADDRESSES DELIVERED AT THE MEETING TO COMMEMORATE THE SEMI-CENTENNIAL OF THE BOSTON SOCIETY OF CIVIL ENGINEERS, NOVEMBER 11, 1898.*

Opening Address by Howard A. Carson, President of the Society.

THE Boston Society of Civil Engineers is now over fifty years old, and we are met to-night to commemorate that fact in a simple and unpretending but I hope pleasant manner. In a short time Mr. FitzGerald will read us what I am confident will be an extremely interesting history of the Society. I think we can feel reasonably sure that our Society will continue to grow and prosper, and that fifty years from now there will be a meeting to celebrate its centenary. As many of our members are young, we may hope that some of those who are here to-night will be present at that celebration, and perhaps give an account of the somewhat quaint old Boston of 1898.

As human beings we are all interested in even the humble details of human life, and, as the effect of the work of engineers is to help feed, clothe, warm and transport the people, illuminate their houses and remove their wastes, we have a special interest in such details. With your permission, I will give a few scattered facts related to life in Boston fifty years ago.

The excellent collection of maps in the City Hall makes it easy to find the outlines of Boston at that day. Most of you are aware that Central Wharf, Long Wharf and other wharves extended up to India street and Commercial street and to the present

*Manuscript received December 29, 1898.—Secretary, Ass'n of Eng. Socs.

Custom House. The Back Bay was then really a bay, and the water came up as far as the west side of the Public Garden, where Arlington street now is, and very nearly to Tremont street at its junction with Dover. The Worcester and Providence roads passed over a long expanse of water in this Back Bay, which was then called, on maps, the *Receiving Basin.* The extension of Beacon street west of the Public Garden was really a Mill Dam, and, as you know, that term has been popularly maintained to the present time. But two or three houses were found west of the Public Garden. The Boston and Maine Railroad, which a few months earlier ran its trains to the city over the Lowell road, was using its new station in Haymarket Square. The building was not nearly so large as that torn down on account of the subway during the last year. The station of 1848 extended no farther north than Market street, while the later one extended as far north as Travers street. The Lowell Railroad station was on Minot street, several hundred feet north of Causeway street. The Fitchburg road had just been extended from Charlestown, and entered the well-known granite structure on Causeway street, which it abandoned to enter the new Union Station four or five years ago. The Eastern Railroad did not enter Boston proper at all, but had its terminal station in East Boston, whence the passengers were ferried to the city. The local rates of fare on the railroads to stations a considerable distance from Boston were apparently about the same as now. You could go to Lowell in an hour. That is still the running time for a train stopping at most of the stations. You can go by an express in thirty-eight minutes. It may be of interest to note that the old Middlesex Canal to Lowell was still running its boats, although the opening of the Boston and Lowell and Nashua and Lowell roads had so reduced its receipts that they did not then cover the cost of repairs and current expenses. The boats continued to run until 1852. The Old Colony Railroad had a station on its present site, and the Boston and Worcester Railroad occupied a part of the station which still exists on Beach and Albany streets.

In September, 1849, there was a passenger train to New York which left Boston at 7 A.M., arrived at Springfield at 10.05, left there at 10.20 and arrived in New York at 4.10, all rail; and there was another train leaving Boston at 4 P.M. which arrived at New Haven at 11.05, connecting there with a boat by which you could arrive in New York the next morning. In 1850 it was possible to leave Boston at 2.30 P.M. and arrive at New York at 11.25 the same night. The price for a ticket to Worcester was then a dollar, the

same as now, and the road had a double track. Although passenger rates are not very different now from those of that day, freight rates, especially for a distance, are very much less. The average price per ton from Boston to Albany in 1848 was $2.80. At present it is about 95 cents. The road carries about sixteen times as much freight as it did then.

Every bridge leading from Boston at that time was a toll bridge. Roxbury, West Roxbury, Brighton, Dorchester and Charlestown were not then parts of Boston. The population of those places and of Boston proper, that is to say all that is included in the legal limits of Boston to-day, was about 174,000, the population to-day being about 526,000. If we take all within a radius of twelve miles, so as to include Lynn, the population at that time was about 290,000, and to-day about a million.

Boston had then had telegraphic communication with New York for two years, the office being in Court Square, where Young's Hotel now is.

Perhaps I may be allowed to mention that Parker, the famous restaurateur, who afterwards established the Parker House, had then a restaurant in a cellar under or near the telegraph office just mentioned. Dr. Green (ex-Mayor) tells me that he had table board there in 1848, paying therefor $3.50 per week. I presume many of our young engineering assistants, with large appetites and small salaries, would be glad if the present Parker House would board them at the rates that then prevailed.

The people of Boston of that day could buy their meat, butter and eggs for prices 25 per cent. less than they now pay, but we can buy to-day clothing and manufactured articles for perhaps 25 per cent. less than what they had to pay for the same article.

Boston had no electric cars, horse cars or bicycles at that date. It had, however, omnibuses running to Charlestown, Cambridge and the South End. The fare to Cambridge was 15 cents. I need hardly say that the telephone did not then exist, and there are hundreds of other less important inventions which had not then been brought into use, such, for example, as the steam fire engine.

In 1848 the Cochituate Water Works had just been completed, and Chesbrough and other engineers employed thereon were later to have a wide reputation.

The illumination of houses at night at that time was mainly by sperm oil and lard oil lamps, but the Boston Gas Light Company was in existence and had about 2000 customers. It has about nineteen times as many now in the same territory. The price was $3.50 per thousand cubic feet then, as against a dollar now.

The steamers of the Cunard Line, the "America," "Niagara," "Canada" and "Europa," were placed on the line between Boston and Liverpool in 1848. Each was a fifteen-day boat a little over 200 feet long, of 1200 to 1500 tonnage and of about eight knots speed. Their latest successors in the passenger business from New York are five and one-half-day boats 620 feet long, and of 13,000 tonnage. Within a year the "Oceanic," of 20,000 tons, 704 feet long, with engines of 44,000 horse power and estimated speed of twenty-seven knots, is expected to lower the colors of the present champions.

It is thought that the following table shows approximately the relative proportions, now and then, of the profitable and non-profitable portions of the loads of trans-Atlantic freight vessels fully laden:

Percentages of weight of displacement on steam freight vessels for a voyage between Boston and Liverpool.

	Hull.	Machinery.	Coal.	Cargo.
1848	45% to 50%	10% to 12%	30% to 40%	10% to 15%
1898	25% to 40%	5% to 10%	4% to 10%	40% to 60%

N. B.—The foregoing figures are not based on equality of displacement or of speed.

If the foregoing table is correct, it appears that there was then required for the voyage between Boston and Liverpool two tons or more of coal for each ton of freight, while to-day one ton of freight can be carried the same voyage with one-eighth of a ton or less.

Among the elements on which this marvelous development is based may be mentioned the substitution of steel for wood and iron in hulls, giving 50 per cent. increase of strength for the same weight; that of compressed and cast steel for cast and wrought iron in machinery, giving still greater advantages; the increase of boiler pressures from 10 to 300 pounds as reported; the increase of engine speed from 50 to 400 revolutions per minute; the multiple cylinder; the surface condenser.

The greatest improvement of all in our material condition is perhaps to be found in what is called the sanitary condition of our cities and our houses. As far as comfort and cleanliness are concerned, we are very much better off than were the people of Boston of 1848.

We may exercise our imaginations in thinking of what will be the condition of Boston when our Society has its centennial celebration fifty years hence. That methods of transportation will have been modified and quickened seems very probable. I will

not hazard a conjecture that flying machines or air ships will be in extensive use. Buildings are much more brightly illuminated now than they were fifty years ago, and the intensity of illumination will probably continue to increase. It is a notable effect of most inventions in the material world that they tend to diffuse comforts and luxuries among impecunious grades of society, and we can safely, I think, predict that this will continue to be the tendency in the future. The daughter of a comparatively humble citizen has a piano to-day. The daughters of day laborers may have them before 1948.

In considering the question of advance in material comfort of the man of 1898 over that of his predecessor of fifty years ago, the question arises, Is the moral condition of the citizen now better than it was then? In 1848 the Mexican War had recently been terminated, but the Napoleonic wars had then been finished for about as long an interval as that since our Civil War. Some writers then believed that the time had nearly or quite arrived when war would cease. During the next generation, however, wars were to follow which, measured by fierceness, loss of life and property and number of men engaged, were as terrible as any known in history. According to geologists, man has lived on the earth for several hundred thousand years, and it is believed that he has been fighting most of that time. The writers of fifty years ago went too far when they supposed that man's savage nature could be so quickly and easily changed. Those who have read the editorials, speeches and sermons of the last few months will conclude that the people of to-day are at least as sanguinary as they were two generations ago.

There is this, however, to be hoped for in the future. If we look back over very long periods it appears that man is not only improving in his environment of physical comforts, but that his nature slowly grows less savage. It seems reasonable to suppose that, as the good things of life become diffused to a greater extent than at present, the people of the future may be somewhat gentler in mood and action than those of to-day, just as well-nourished people around a plentifully spread table politely regard each other's rights and comforts, as compared with emaciated hungry men scrambling for scanty food.

I have now spent as much time in talking about the Boston of fifty years ago and conjecturing about the Boston of the future as should be so devoted by me this evening, and I take great pleasure in calling upon Mr. FitzGerald for the history which you are eagerly awaiting.

Historical Address by Desmond FitzGerald, Past-President of the Society.

Fifty years have now passed since a small band of engineers met in Boston for the purpose of organizing a Society of Civil Engineers, and to-night we are gathered to celebrate the semi-centennial of that Society.

Fifty years ago, not only the Boston Society of Civil Engineers, but the profession of engineering itself, was struggling to gain a footing in this country. To-day the child has grown to be a man. To-day we not only realize that the profession stands on a strong and vigorous foundation, but we also know that the present eventful period, rich with the light of progress, opens to the profession opportunities for usefulness and advancement which could hardly have been dreamed of when the foundation stones were laid.

Our corporate existence to-day, although a respectable one, is yet but the first flush of strong and vigorous manhood, which looks back upon the days of youth with interest not unmixed with wonder, and turns to the future as to a beneficent harbinger of prosperity.

On April 26, 1848, an informal meeting was held at the United States Hotel in Boston to consider the expediency of taking measures to form a society for social intercourse and professional improvement, to be composed of civil engineers and of gentlemen engaged in pursuits kindred to civil engineering. Of about twelve persons invited there were present: John H. Blake, E. S. Chesbrough, George M. Dexter, Henry S. McKean, William S. Whitwell.

Of these five engineers two only remained in practice to the ends of their lives; one of these worked his way to the very front rank, and the other ended his own life in disappointment and despair. The remaining three followed pursuits other than engineering.

This was the first meeting of engineers in the country gathered for the purpose of forming a society from which any tangible results followed. If it could be considered as the first meeting of the Boston Society of Civil Engineers, then the birth of the French Society, which, by a happy coincidence, was founded on March 4, 1848, preceded our own by only a little over a month and a half. This is, of course, enough to give the French Society all the honor that may go to the first-born. The Boston Society of Civil Engineers was not formally organized, however, until June 15. The first meeting was held on July 3, which date has been, I

think erroneously, accepted as the date of organization. If June 15 be adopted as the date of organization, then our sister French Society is our elder by three months and eleven days, and to this extent at least we must acknowledge her superiority.

The foremost association of engineers in the world, the Institution of Civil Engineers of England, received its charter of incorporation June 3, 1828, although meetings were held prior to that time as far back as 1817. Telford was the first President. The property of the institution is now valued at $500,000, and the ordinary income of the Society is $125,000.

Whatever our standing may be in point of age when compared with foreign societies, our glory at home is unquestioned. The American Society of Civil Engineers was instituted November 5, 1852, and is, consequently, four years and five months our junior. The Engineers' Club of Philadelphia dates from December, 1877.

From 1848 to the present time, the light of the Boston Society has burned continuously and brightly, with the exception of that little gap from 1861 to 1874, when the oil was being replenished.

The following is a list of the early members of the Society, 1848-1861: Samuel Ashburner, Waldo Higginson, James F. Baldwin, Isaac Hinckley, Joseph Bennett, Josiah Hunt, John H. Blake, Martin B. Inches, Simeon Borden, Samuel F. Johnson, Uriah A. Boyden, James Laurie, E. S. Chesbrough, Henry S. McKean, John Childe, Samuel Nott, Marshall Conant, George A. Parker, Franklin Darracott, William P. Parrott, William L. Dearborn, T. Willis Pratt, George M. Dexter, Theophilus E. Sickles, Sereno D. Eaton, Lucien Tilton, Robert H. Eddy, William S. Whitwell, Samuel M. Felton, Thomas S. Williams, James B. Francis.

The following were Presidents of the Society, 1848-1861: James F. Baldwin, George M. Dexter, Simeon Borden.

Obituary notices have never been prepared of either of the early Presidents of the Society. It is a token of love which should be undertaken, and that before it becomes too late.

The first officers of the Society were: President, James F. Baldwin; Vice-President, George M. Dexter; Secretary, John H. Blake; Treasurer, William P. Parrott; Directors, Samuel Ashburner, Joseph Bennett, James Laurie, Samuel Nott, William S. Whitwell.

The most frequent attendants at the early meetings were: Messrs. Ashburner, Bennett, Chesbrough, Dexter, Nott, Parrott and Whitwell.

Among the early members may be particularly mentioned Samuel Ashburner, Samuel M. Felton, James F. Baldwin, James B. Francis, Simeon Borden, James Laurie, Uriah A. Boyden, Samuel Nott, E. S. Chesbrough, Theophilus E. Sickles, distinguished engineers, who left their mark in the profession.

James F. Baldwin was one of a large and celebrated family of engineers, of whom Loammi was considered by some to be the father of his profession in the United States. James was a railroad engineer. He built the Boston and Lowell Railroad, wrote a treatise on railroad curves, and was one of the commissioners to introduce the Cochituate water into Boston.

Borden established what have always been known as the Borden points in the trigonometrical survey of the State. Boyden brought the turbine to the highest degree of perfection. Chesbrough shared with Francis the highest pinnacles of fame in the profession; the former's work was particularly identified with the water systems of Boston and Chicago, and the latter was known all over the world as a leader in hydraulic science and its application in the magnificent water development at Lowell. Felton became a distinguished manager of railroad properties.

James Laurie was a well-known railroad engineer, and was at one time chief engineer of the New Haven, Hartford and Springfield Railroad. While engaged on this railroad he designed and built the bridge across the Connecticut River at Warehouse Point. This bridge, for that period, was one of the most remarkable in the country. It was a riveted iron bridge built in England. One of its spans was 177.25 feet long. The cost of the bridge, erected and completed, was 12.38 cents in gold per pound.

Mr. T. E. Sickles was at one time chief engineer and general superintendent of the Union Pacific Railroad. In 1874 he was designated by the President, General Grant, as one of a commission of seven engineers to recommend to Congress the proper method for securing an open mouth to the Mississippi River. In 1876 he was one of the judges of the Centennial Exposition in Philadelphia, and in 1878 was a representative of the American Society of Civil Engineers at the Paris Exposition. He was a man of remarkable originality and of independent judgment.

This is a brilliant array of talent for the early founders of any learned society, and one of which we may justly be proud. The pioneers of the profession were men of industry, which is better than genius; of sterling integrity, which is better than brilliancy; of determination, which is sure to bring success. They were self-made men, whose whole lives were given to study; who denied

themselves pleasure and recreation to make up by close application for deficiencies in training. Who can recount their early struggles against poverty and their steadfast devotion to the highest aims? Their characters, their works and their attainments are their best epitaphs. Many of them lived to see that enlargement of the professional field and the dawn of that wonderful prosperity which have characterized the last generation.

It is interesting to glance at some of the topics of discussion at the early meetings in 1848. We have "The Coal and Iron Trade of Great Britain and the United States," by James Laurie; "The Carrying of Water Pipes to South Boston," by W. S. Whitwell, and by the same author a description of the Beacon Hill reservoir, a reservoir which was expected to last for centuries, but which was removed a few years ago as having outlived its usefulness; Mr. Chesbrough, on contracts; Mr. Blake, on the use of lead pipes for carrying water; the failure of the dam at Hadley Falls, by Messrs. Nott and Parrott.

On September 3, 1849, Mr. Kyan, of London, appeared before the Society and gave an account of the kyanizing process for the protection of timber.

On September 11, 1849, occurred the death of Major George W. Whistler, one of the most distinguished members of the profession in the United States, and probably at that time the civil engineer of widest fame. Major Whistler was selected by the Czar of Russia to build the railroad from St. Petersburg to Moscow, and for this he was decorated with the Order of St. Anne. A committee of five was appointed to attend the funeral at Stonington.

On December 3, 1849, the feasibility of the project of building a railroad to the Pacific was discussed.

The explosion of locomotive boilers seems to have been a rather frequent occurrence in those early days, and the Society was often called upon to investigate the causes of these explosions.

In 1850 appeared Mr. Bennett's translation of D'Aubuisson's "Hydraulics," a standard treatise, which, at that time, was supposed to represent the accumulated knowledge of the world on that subject. The translation into English by one of its own members was a work in which the Society felt a proper pride. The translation was dedicated to the Boston Society of Civil Engineers.

The early transactions of the Society have been neatly copied into a quarto MS. volume, which is preserved in the library.

On April 24, 1851, an act to incorporate the Boston Society of Civil Engineers was obtained from the Legislature, and the

names of George M. Dexter, Simeon Borden and William P. Parrott appear as incorporators. It is under this act, authorizing us to hold real and personal estate, not exceeding in amount $20,000, that we now exist.

On February 9, 1852, the act was accepted by the Society. The membership at that time was twenty-seven, and the average attendance at the meetings about twelve.

Previous to June 3, 1853, the Society had its room at No. 114 Joy's Building, but after this it met at the room of the Association of Railroad Superintendents, No. 11½ Tremont Row, where, by mutual agreement, the two Societies used the rooms and the library in common.

The Society continued in a prosperous condition, holding regular meetings, which were generally well attended, until the spring of 1855. After this time but very few meetings were attended by a quorum, and consequently no business could be transacted.

In 1860, the lurid cloud of the War of the Rebellion appeared upon the horizon, and when the storm burst the excitement and trouble swept the existence of the Society before it. The modest assets were sold, all debts extinguished and the balance, $1.53, given to the Boston Athenæum, where the records and about one hundred other books were deposited for safe keeping.

The property of the Society reposed peacefully on the shelves of the Athenæum while the waves of war beat upon the land, and when at last the sunshine of peace was fairly established they were resurrected to form a foundation for the second period of existence of this Society.

To this period we will now turn.

On May 30, 1873, a number of engineers in Boston and vicinity organized as "The Boston Society of Civil Engineers," and held meetings, mostly at the Massachusetts Institute of Technology. It was soon brought to the notice of this body that they had unwittingly taken the name of a society which in fact existed, although in a state of desuetude. Proper legal steps were at once taken to revive the real Boston Society of Civil Engineers, with its Legislative charter. Three of the original members—Messrs. Darracott, Pratt and Higginson—petitioned a justice of the peace to issue an order requiring Franklin Darracott, in the name of the Commonwealth, to call a meeting at the office of Mr. Ernest W. Bowditch, at 60 Devonshire street, on the 27th day of April, for the purpose of choosing officers, and directing notices to be sent to all the known members of the original Society. It was found

that there were eighteen living members, and they were all duly notified.

Pursuant to this warrant, a legal meeting was held as above, at which five members were present,—viz, Messrs. Francis, Darracott, Higginson, Nott and Pratt. Mr. James B. Francis was elected President and Mr. Samuel Nott Secretary.

Eighty-eight new members were elected, these members being those already included in the list of members of the Society formed May 30, 1873.

On June 8, 1874, the officers of the newly reorganized Society tendered their resignations, and on August 7 Mr. Thomas Doane was elected President and Mr. George S. Rice Secretary.

At the meeting on September 4, 1874, the organization was completed by the election of other officers, and in October a constitution and by-laws were adopted, and the old Boston Society of Civil Engineers was fairly launched on its second period of existence.

It is worthy of notice that the first paper read before the reorganized Society was on the Metric System.

In 1874, when the Society was reorganized, the first meetings were held at the Massachusetts Institute of Technology, which has always generously opened its doors to the Society whenever the latter has found itself homeless. In 1875 and during the early part of 1876 a room was obtained at 66 State street and fitted up for the Society. Meetings were held here until May 17, 1876, when a move was made to the small committee room in the rear of Wesleyan Hall, 36 Bromfield street. In these cramped quarters the Society remained for nine years. It seems almost incredible that the Society could have been content with these premises for so long a time; and yet, during these years, many important meetings were held and many interesting professional questions discussed. On October 21, 1885, another move was made, this time to the station of the Boston and Albany Railroad, where a room on the upper floor was kindly furnished by the railroad company, free of charge, for the common use of this Society and the New England Railroad Club. The Society remained at the Boston and Albany Station for four years.

It was at this time that the members formed the habit of dining together on the evenings of the meetings, a custom which has been happily preserved to the present time, and which it is hoped will never be given up.

It was in the room at the Boston and Albany Station that the library for the first time became really accessible.

In 1889 the railroad company wished to make use of its room, and in September the Society was obliged to withdraw to the Institute of Technology.

After trying several places, a room was finally obtained at the American House, on Hanover street, where the meetings were held for more than two years. The library was placed in a small room near the larger room in which the meetings were held. The principal advantage of the American House location was the opportunity afforded for dining on special occasions in a large hall at a moderate price. It is easy to recall many delightful meetings held at the American House and attended by some whose faces will, alas, never be seen with us again.

In June, 1892, the Society again moved its quarters to Wesleyan Hall, but this time to the large hall, for which favorable terms were secured. A room near the hall was obtained for the library, and here many informal meetings were held for the discussion of passing events of engineering interest. A table in the center of the room was well covered with current professional literature. It was not long before the shelf room was outgrown, and it became evident that, to gain the full advantage of our growing library, larger quarters must be secured.

During the autumn of 1894, efforts in this direction were begun, and in October, 1895, an agreement was reached with the trustees for the new Tremont Temple building for the use of a portion of the seventh floor. In March, 1896, a lease was executed for three years, with the privilege of renewal for three years more. The rooms, together, measured 18 by 43 feet, and a mutually advantageous arrangement was made by which the New England Water Works Association and the Hersey Manufacturing Company were to share the use of the rooms. On the floor below the library was Chipman Hall, a convenient and spacious hall for the meetings of the Society.

On May 20, 1896, the semi-centennial anniversary of him who is now addressing you, who will long have occasion to remember it with pleasure and gratitude, the Society moved into the Tremont Temple. When compared with anything enjoyed heretofore, the new quarters of the Society seemed indeed palatial. The shelf room appeared ample for a number of years. The furniture and appointments of the library were all in the best of taste. The bookcases, however, have filled rapidly, and they already give warning that even these delightful quarters will soon become severely taxed.

We have now become so accustomed to having a Committee

on Quarters that a permanent committee has become grafted onto our list of officers, and seems as necessary for our welfare as any other of the permanent committees of the Society.

A commodious and well-appointed club house, fitted to the growing needs of the profession, has been the dream of the members for several years.

I believe it has been generally felt that all of our many abiding places, covering a long pilgrimage since 1874, not unlike that of the Children of Israel, are simply temporary homes, endured patiently for the time being, while the Society gains in growth and slowly but steadily advances in material prosperity.

It is a gratifying fact that so far no false step has been made, and all of our financial transactions have been marked by a wise conservatism.

In 1878 the permanent fund amounted to $1,000, invested in a five per cent. United States bond. In 1889 the treasury contained $3,095.86, and in 1898 the permanent fund has accumulated to $8,423.01. The current expenses of the Society are about four thousand dollars yearly.

Some idea of the early resources of the Society, after its reorganization, may be formed when it is considered that in April, 1877, the Secretary was directed "to ascertain the cost of printing a list of members and report." The number of members at this time was seventy-two. The average attendance was eighteen. In 1888 there were two hundred and fifteen active and four honorary members. The average attendance of members and visitors was seventy, the maximum one hundred and fourteen and the minimum forty-eight. In 1898 the number of members has risen to four hundred and fifty-five, with five honorary and five associate members, and the average attendance is about ninety-five.

In March, 1879, the sum of $200 was appropriated to print the papers and proceedings, and, as a result, appeared the first printed records from September 17, 1879, to June, 1881, both inclusive, forming a volume of one hundred and forty-four pages.

On January 19, 1881, an important step was taken when it was voted to join the Association of Engineering Societies, an Association formed for the purpose of a joint publication of the papers and proceedings of the Societies forming it.

From June, 1881, to the present time, the papers and transactions of the Boston Society have appeared in the printed journal of the Association.

The present prosperity of the Association of Engineering Societies is largely due to the intelligent and persistent efforts of

our honored Secretary, Mr. S. E. Tinkham, who was a member of the Board of Managers at its organization and for several years its chairman, and to Mr. John C. Trautwine, Jr., Secretary, who has held that office for the past four years. Under this management the mailing list of this Association has risen to twelve hundred and fifty-two.

The growth of our library has been a gauge of our increasing strength. In 1878 the number of books was merely a handful. In 1888 the bound volumes amounted to five hundred and ten. In 1898 the library has risen to the dignity of thirty-two hundred and twenty-six. To the disinterested efforts of Messrs. Clarke, Brooks, Kettell, Noyes, Woods, Hodgdon, Bryant, Locke, Flinn, Fuller and Fales the members are greatly indebted for the present dimensions of our library and for the convenience of its arrangement.

For a number of years past we have been in the habit of enjoying together an annual dinner, and this feature, together with the monthly excursions, have, in a measure, become settled institutions. The first annual dinner was in March, 1883. Until 1890 the annual meetings and dinners were held together, but after an experience of seven years it was thought best to make the dinner a separate feature held on a different day, and this custom has prevailed to the present time. Our last dinner, in March of this year, was the sixteenth in succession. There were present at the tables one hundred and sixty-one members and guests. It is needless to say that many good things besides the viands are passed around on these occasions. This happy institution will receive a serious blow when Mr. Henry Manley ceases to take an interest in the preparations for this event.

The plan of making excursions to various points of engineering interest in the vicinity of Boston was begun in 1885, and in 1886 the government was authorized to appoint a Committee on Excursions. This feature has proved successful, although the wonder grows where the able Committee on Excursions continues to find new fields for explorations. Perhaps it is one of the duties of the profession to build new works fast enough to keep up the supply.

If I had been mentioning the officers of the Society in the order of importance, I should have put the Secretary first. It needs no feeble words of mind to gild the work which our present popular and devoted Secretary has so faithfully performed for this Society for so many years. Long may he be spared to sign the calls for our meetings, and long may he hold the idea, even if he

does not already hold it, that the office is his by right of propriety and possession. Mr. Tinkham was first elected Secretary in April, 1880, and he has held the office ever since, with the exception of the period from 1882 to 1887, when Mr. Horace L. Eaton was Secretary.

Long as Mr. Tinkham's term has been, it was exceeded by that of Mr. Samuel Nott, second Secretary of the Society, who held office from March 6, 1849, to August 7, 1874. The Society is fortunate in having Mr. Nott present to-night. He is the only one of the founders who is able to attend our semi-centennial. The work which he performed for the Society so many years ago is fully appreciated by the present members, who have reaped the benefits.

Honored sir,—you have come down to us from the very foundation of the Society. You alone of your contemporaries have been spared by divine providence to witness here to-day the development of that seed planted in 1848, from a handful of professional brothers to the strong and vigorous Society that you see here to-night. You never could have foreseen that the passage of fifty years would change to such a degree the status of the profession to which your long life has been devoted, and it will be ever a consolation to your declining years to know that to you and to others of your co-laborers was given the honor of founding the Boston Society of Civil Engineers, the first organization of engineers in America.

For our part, we desire to extend to you our hearty congratulations, and to wish you that well-earned happiness which is the accompaniment of a long life spent in the service of your fellow-man.

After Mr. Nott's retirement, Mr. George S. Rice held the position for six years and most acceptably to the Society.

The early Presidents have already been alluded to. Since 1874 the Society has had fifteen Presidents, as follows: Messrs. Francis, Doane, Davis, Vose, L. F. Rice, FitzGerald, Herschel, Stearns, Manley, Freeman, McClintock, Noyes, Swain, Brackett and Carson, an honored list, in whose company any one may well be proud to be enrolled.

I come now to our deceased members,—a list which is naturally scanned with a sad heart, it contains so many whose faces have been familiar at our meetings and whose presence was an inspiration to our own lives. There are fifty-six names on this list. I have taken upon myself the privilege of preparing brief biographies of these deceased members, for convenience of refer-

ence, forming an appendix to this address,—a few words only for each, but sufficient as an index to the principal life work of each one.* There are three names, however, upon which I must here linger for a moment, as they represent three Past-Presidents of the Society since its reorganization, who have passed to their long reward.

The life and work of James B. Francis are already well known, and I will not attempt to reiterate what has already been so fully portrayed. Mr. Francis was the first President under the reorganization and for a very brief period. His home was so far from Boston that he could not conveniently take part in our proceedings, but his counsel and advice were frequently sought, and never in vain. We all hold his memory precious. He was a true type of the civil engineer,—of sturdy integrity, possessed of brilliant abilities combined with soundest common sense. He climbed the ladder of fame with a sure and steady footstep. His great work in the development of the water power of the Merrimac River at Lowell will always remain as a remarkable achievement in the history of hydraulic engineering on this continent.

"Let us weep in our darkness, but weep not for him;
* * * * * * * *
Not for him who has died full of honor and years;
Not for him who ascended Fame's ladder so high;
From the round at the top he has stepped to the sky."

Thomas Doane was President of this Society for nine years,—1874 to 1884,—and was for twenty years an active member of the Society. He probably took as deep an interest in the welfare of everything connected with this organization as any member inscribed upon its rolls. It seems but yesterday that he was here to aid in our counsel and to add some item of engineering interest to our meetings. Mr. Doane was best known as a railroad engineer, and at one time or another, I believe, he was connected with almost every railroad leading out of Boston. He was Chief Engineer of the Burlington and Missouri River Railroad. Much of his interest was centered in the development of Nebraska, and he was the founder of Doane College in that State. Many a day will elapse before the Society finds a truer friend than Thomas Doane.

Mr. Albert F. Noyes, who was President in 1895, passed away in the prime of life, and so recently that we can hardly realize that he has gone on that long and mysterious journey from which there is no return. Mr. Noyes was long and prominently connected with the advance of this Society, and he filled many of its offices

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*Omitted.

before he was called to preside at our meetings. If Mr. Noyes had been more sparing of his own strength and more considerate of his own comfort, he would probably be with us to-night to share our pride in this delightful celebration of an event in the history of a Society which he loved so well and for which he labored so faithfully.

Mr. Noyes was City Engineer of Newton for sixteen years, from 1877 to 1893, and brought that office to a high degree of efficiency. He was afterwards connected with the work of the State Board of Health, and in 1895 was appointed on the Metropolitan Sewerage Commission, where the Commonwealth received the benefit of his ability and experience.

Time will not permit me to name other honored members of the Society, who, in one office or another, have contributed to its welfare. The men whom we meet here night after night and year after year are men of sterling worth whom to know is to respect, and who can be trusted in all the emergencies of life. It is gratifying to know that the public is taking the same view, and that in one place or another important positions are thrust upon our members outside of their regular professional duties. As I scan the list, I find many who hold positions on State, municipal or town commissions, where their influence is always felt on the right side of public questions. A friend remarked to me facetiously, not long ago: "You engineers are fast absorbing to yourselves all the best places in life." I could not help smiling at the thought, especially as my friend happened to be a member of the bar.

Among the passing tokens of regard with which the public are beginning to appreciate the work of the profession, it is worthy of notice that the only name which appears upon the portal of that recent triumph of engineering skill, the Boston Subway, is that of our worthy President, Howard A. Carson, a graceful tribute by the commissioners to his ability and achievements.

In what has already been said, I have attempted to give an historical account of the formation and progress of this Society during the past fifty years. Such a narrative must necessarily deal with facts which can be of little interest outside of our own membership, and with statistics which, I am afraid, tax even your patience. I trust, however, they may at least be useful in bringing to your minds the paths, more or less familiar, which we together have been following at different times in this eventful half-century, —paths at times clouded by the passing storm, and perhaps even at times by failure, but more often illumined with the bright rays of success and of progress.

In the laborious and responsible work of the profession there is little time for looking backward; the swimmer who turns his eyes from the goal is cast into the eddy; but there are times when retrospection is profitable, and a glance into the past, at least once or twice in a century, is instructive and at least pardonable.

As we consider the record of this Society, founded by the early toil and constant struggles of the fathers of the profession, built solidly on the eternal principles of truth and honesty, and rising slowly but surely out of every discouragement to its present commanding proportions, we have reason to be proud,—proud of our Society, and proud of the achievements of our members in every branch or specialty of the work of the civil engineer, who, by patience, by industry, by ability, and, best of all, by unswerving integrity, have aided in lifting the noble profession of engineering to its place among the great professions of the world.

THE NATURE AND HISTORY OF PATENT RIGHTS.

By E. L. Thurston, Esq., Associate Member of the Civil Engineers' Club of Cleveland.

[Read before the Club, December 13, 1898.*]

The patent rights to which this paper relates are those rights respecting an invention which are created by the grant of a patent for that invention.

Until a patent is granted for it an inventor has no property rights whatever in his invention as such. It is true he may own the particular machine or instrument in which his invention is embodied, but he has no ownership in the invention itself until the patent is actually granted and issued. In the meantime others may make, use and sell similar machines or instruments containing the invention without infringing upon any of the inventor's rights. Under the common law every person has the right to make anything he wishes to make out of materials which he owns, and it is equally his right to sell the thing so made or to use it when and where he chooses, provided such use is not harmful to the public. It is only by the grant of a patent, authorized by the statute laws passed by Congress, that an inventor acquires any special rights or privileges respecting his invention.

The right created and secured by a patent is, to quote from the granting clause of a patent, "the exclusive right to make, use and vend the invention throughout the United States and the territories thereof" for seventeen years. The language quoted is ambiguous and deceptive, and is responsible for a widespread misapprehension as to the nature of the rights secured by the patent. Many persons believe that a patentee has, by virtue of his patent, the absolute right to make, use and sell his invention; but that is not the fact. The patent secures to him the "exclusive right to make, use and sell his invention," but to understand just what this right is you must put the accent on the word "exclusive." A patent secures to the patentee the *exclusive* right to make, use and sell his invention. The patent is a grant of exclusion, and that only. It secures to the patentee the right to exclude or prevent others from exercising their natural right to make, out of their own materials, the particular article the invention of which the patent covers; and that is the only right respecting an invention which is created by a patent. It does not give or purport to give to the inventor absolute right to make, use or sell his invention.

*Manuscript received December 31, 1898.—Secretary, Ass'n of Eng. Socs.

If he had that right before his patent was granted he has that right after the grant, but otherwise he has not.

As I previously stated, it is the natural right of every person to make what he wishes out of his own material, but each patent which is granted to another restricts that right. It removes for seventeen years the particular invention which it covers from the group of things which the public may use and sell. There are now in force more than 360,000 patents, each of which acts to thus restrict the natural right of every person except its owner; because, as before stated, the owner of every patent has the right to prevent you and me and everybody else from making, or using or selling the invention which his patent covers. Clearly, the grant of a patent to one of us can not take away the right previously granted to another; and in many cases it would do that if it granted to the patentee the absolute right to make and use his own invention. Most inventions are improvements upon, or changes in, or modifications of, or additions to, old things. The first inventor of every improvement has the right to a patent by which he can prevent others from using it, but he may not be able to make use of it himself because some previous patent may have secured to its owner the right to prevent others from using some part of the thing improved, without which the improvement is useless.

A familiar example of this condition of things existed for many years with respect to the telephone which was invented by Bell, who was granted a broad patent for his invention. Before this Bell patent expired more than five hundred patents for improvements on the telephone were granted. These improvements were of all kinds, good, bad and indifferent; but, whether good or bad, the patentees could not use their own patented inventions, because in so doing they would necessarily use Bell's invention and thereby infringe Bell's patent; or, in other words, they would do that which Bell, by virtue of his patent, had the right to exclude them from doing. Under conditions like these there is a sort of deadlock. The owner of the original patent cannot use the improvement without the permission of the owner of the improvement patent, and the latter cannot use his improvement without the permission of the former. Ordinarily, if the improvement is valuable, the two get together upon some equitable basis.

Although, as I have stated, property rights in an invention, as such, do not exist under the common law, and may be secured only by the granting of a patent, inventors in this country are not dependent for the grant upon the caprice of any one. Congress has enacted patent laws by virtue of which the first inventor of any

new and useful art, machine, manufacture or composition of matter has the positive right to the grant of a patent upon complying with certain prescribed conditions. Congress derives its authority to pass patent laws from the Federal Constitution, wherein it is set forth that "Congress shall have power to promote the progress of science and the useful arts by securing to authors and inventors for a limited time the exclusive right to their respective writings and discoveries."

The wise framers of our Constitution recognized these facts, which our history as a nation has abundantly substantiated,—viz, first, that progress in the useful arts would be promoted by stimulating invention; second, that invention could be stimulated by offering a reward to inventors, and, third, that the fairest method effecting that result would be to make the reward as nearly as possible commensurate with the value of the invention to the public. In theory, at least, no better method could be devised than that which gives to the inventor, for a limited time, the control of his invention. He may, within that time, make out of his invention such profit as the public demand for it or its product will yield. If the invention be valuable to the public the inventor's profits will be correspondingly large. If the invention be of little importance the inventor's profits will be proportionately small.

The legal machinery for enforcing the patent laws, to the end that the inventor may obtain his promised reward, is not perfect. Like other machinery, it sometimes works better in theory than in practice. I believe, however, that the rights of a patentee may be enforced as speedily and as effectively as can any other right which must be enforced by law.

There are two theories as to the nature of a patent right. Under one theory it is a monopoly. Under the other theory it is a contract between the inventor and the Government representing the public.

The contract theory is fortunately that which has been generally accepted by the courts and by Congress in this country. Under the contract theory the Government may be said to have a standing offer to inventors in substantially this form: The Government will grant to every inventor for seventeen years the exclusive control of his invention, provided it be new and useful, and provided he will, in the manner and form prescribed, make a full and complete disclosure of the invention to the public, so that the public may understand how to make and use it after the term of the grant has expired.

An inventor is under no obligations to accept this proposition.

He may lock the invention in his own mind, where it was born. He may practice it in secret if he chooses to, and if the nature of the invention will permit it. If he does accept the proposition the public gains the complete knowledge of the invention, and, in compensation for this knowledge disclosed by the inventor, he acquires the exclusive right to control the invention for seventeen years.

This exclusive privilege does not take from the public any right which it had before enjoyed, because it is one of the essential prerequisites of a valid patent that the invention must be new. The only hardship which the grant imposes upon the public is that it must for a time either do without that which it never had or that it must obtain the right to use the invention, if at all, upon the inventor's own terms.

In the eyes of the law it is not unimportant to determine definitely whether a patent is a monopoly or a contract. It is not a mere question of words. If a patent is a monopoly it is a grant in derogation of common right, and as such it should be construed strictly against the patentee and in favor of the public. The language of the patent should be carefully and critically examined, and whatever is not positively and unequivocally included in the grant, whether invented by the patentee or not, should be held to belong to the public.

If, on the other hand, the patent is a contract it should be construed, as all contracts should be, liberally and fairly, and as nearly as possible in accordance with the intention of the parties as expressed by the patent. It is always the intention of an inventor to secure complete protection for his entire invention. It is the promise of the Government that he shall receive complete protection for that invention which the patent covers. Under the contract theory the patent should not be subjected to over-nice criticism. If the language employed by the patentee in his claims will permit such construction, it should be construed so as to afford complete protection not only for the particular embodiment of the invention shown and described, but for its mechanical equivalents. This, fortunately, has been and is the attitude of our courts upon this subject. It sometimes happens, however, that the claims of patents are so unskillfully formulated that their language cannot be construed to protect the invention. Under the contract theory the patent is the contract instrument. The specification and drawings constitute that part of the instrument which discloses the invention, and it is the consideration passing from the inventor to the public. The grant, found on the first page of a patent, is the consideration passing to the inventor from the public, and the

claims define the subject of the grant. The claims are brief statements made by the inventor, or his attorney, which point out which part or parts of the entire thing described the inventor claims to have invented. It is left to the inventor to make his own definition of the boundary of his grant. If he claims too much the Patent Office will refuse the patent. If he claims too little the patent is granted only for what he claims, and he loses part of the protection which he might obtain. It is therefore very essential that the claims of a patent shall be skillfully drawn, because the courts, while they will liberally construe the claims which are in a patent, will not make new claims and will not construe the claims to mean something which their language plainly does not mean. Many a valuable invention has been sacrificed by unskillfully drawn claims.

Let us now consider briefly the other theory of the patent privilege,—viz, that it is a monopoly. The patent right is undoubtedly a monopoly in a limited sense. But it is not an illegal monopoly, as defined by Blackstone and all of the later legal writers. Blackstone defines a monopoly as "a license or privilege allowed by the King for the buying, selling, making, working or using of anything whatsoever whereby the subject in general is restrained from that liberty of manufacturing and trading *which he had before.*" A patent right is not a monopoly in that sense. It does not, as a matter of fact, deprive any individual of any right he had before, because, as before stated, it is one of the essential prerequisites of a valid patent that the patented invention must be new. It must never have been known to or used by others before the inventor originated it. And no individual can be said to have been in actual possession of a right when neither he nor any one knew how to exercise that right. The patent right is monopolistic in form only, but so also is every property right. A man who owns a horse or a house, or any other thing, has, by virtue of that ownership, the exclusive right to use that thing.

The theory that the patent privilege is a monopoly had its origin in the fact that the early history of the British patent system, of which our patent system is the direct descendant, is inseparably connected with the history of those illegal monopolistic grants by the English kings, against which the famous Statute of Monopolies was aimed.

Briefly, the early history of the birth and growth of the British patent system is the following: In the early history of trade and manufacture in Europe capital was timid. It needed encouragement and protection. The people in those days were not strict

observers of the rights of property. Might made right. The beginning and carrying on of trade and business was hazardous. Communication between different cities and countries was difficult and dangerous; and the assurance of large profits upon successful ventures, to balance losses upon unsuccessful ventures, was necessary to tempt capital into trade, and especially to induce merchants to engage in foreign trade, which would bring into the country new manufactures; that is to say, new manufactured things and the knowledge of the art of making them. To encourage capitalists to enter trade and manufacture the English kings at an early day began to exercise their royal prerogative by granting special privileges to such persons. The promotion and development of towns as centers of domestic trade and manufactures were also encouraged by royal grants of political immunities or commercial franchises.

Practically all of the early royal grants of special monopolistic privileges had been made directly to merchants, or to manufacturing or trading companies, as inducements to enter business, or as rewards for having done so. But later the crown began to grant monopolies for money paid or for services rendered the crown. Monopolies were sold by the crown to persons who sold them again at a profit. Favorites were rewarded by grants of monopolies; and this evil increased until competition was destroyed and trade in almost all commodities was controlled by a few individuals, who put upon these commodities whatever price they pleased. Such common articles as salt, iron, powder, vinegar, bottles, oil, starch, paper, etc., were the subject of monopolies.

Grants of this character took from the people rights and privileges which they had before enjoyed, and were consequently odious monopolies; and the burden of them became so great that in the reign of James I (1623) the famous Statute of Monopolies was finally enacted by the British Parliament, and the King was forced to sanction it. By this statute all past monopolies were abolished, and the power of the King to grant others was expressly denied, except where such grants had been or should be made to inventors of new manufactures, conferring upon them for a limited time the exclusive right to practice their inventions.

Prior to the enactment of this statute two classes of monopolies, widely different in both their legal and intrinsic characters, had been granted in England. The first class, and the earliest to be granted, comprised those which conferred upon the inventors of new manufactures, or the introducers of a new trade into the realm, the exclusive right of carrying on that trade or manufacture

for a specified period. The English courts always sustained these grants as the proper and legitimate exercise of the royal prerogative.

The second class deprived the public of the right to make or sell those things which before the grant they had the right to make or sell. The grants of this class were always treated by the English courts as odious and void at common law. But, since the courts had no power to prevent the crown from making such grants, they could only punish the monopolist for procuring them and prevent him from exercising them; and these things they invariably did when occasion offered itself.

This statute, therefore, merely enacted into statutory law those principles which the English courts had always declared to be the common law of England.

The framers of our Constitution were well acquainted with those principles and with the reasons which induced the English courts to sustain grants of special privileges to inventors. They recognized both the justice of such grants and the advantages which wise patent laws would bring to the public, and they therefore incorporated into the Constitution that clause which I have quoted.

Acting under the authority thus conferred, one of the early acts of Congress was to pass the first patent statute, which went into effect April 10, 1790, and was entitled "An Act to promote the progress of useful arts."

The Act of 1790 specified the subjects for which patents might be granted as the "invention or discovery of any useful art, manufacture, engine, machine or device, or any improvement thereon not before known," and patents were granted for fourteen years. The act remained in force about three years, and only fifty-five patents were granted under it. The first patent granted under this act was dated July 31, 1790, and was granted to Samuel Hopkins for making pot and pearl ashes.

On February 21, 1793, another act took the place of that of 1790. Under this act the applicant for a patent was required to make oath that he believed himself to be the true inventor. This was not required under the Act of 1790.

By an act passed February 15, 1819, an important change in the mode of administering and enforcing the patent law was introduced. Under the previous acts all suits for infringement of letters patent were necessarily suits at law for damages. Under the Act of 1819 the Circuit Courts of the United States were given jurisdiction in equity, as well as in law, of actions for the infringe-

ment of patents, with power to grant injunctions to prevent the violation of the rights of the inventors. No other provision for the protection of the rights secured by patents has been so effectual as this power to restrain infringements by injunction. It is constantly invoked. In fact, nearly all patent suits for many years have been suits in equity asking for an injunction, among the other reliefs prayed for. Without this right of granting injunctions the courts could not practically secure to inventors the exclusive right to their inventions which is contemplated by the Constitution.

By the Act of 1832 the right was conferred upon a patentee to reissue his patent, provided the patent is inoperative or invalid for certain reasons stated which arose through inadvertence, accident or mistake, and without any fraudulent or deceptive intent on the part of the inventor. The reissued patent was to remain in force during the unexpired term of the original patent. This right to reissue a defective patent has been retained in all of the subsequent acts, with no substantial change in the conditions prescribed.

During the period of a little more than forty-six years after the enactment of the first patent statute, in 1790, the number of patents granted was a few over 6000, a number now greatly exceeded in every period of four months. During the past forty-six years the number of patents granted is over 600,000. The greatest number of patents granted in any one year prior to 1836 was 751. The number granted in the last twelve months is over 20,000.

In 1836 all of the preceding acts were repealed, and a new act was passed by which was inaugurated a new system for the granting of patents. The Act of 1836 introduced a radical change in the patent law, so far as it related to the granting of patents. It created an office or bureau to be called the Patent Office. The act provided for the appointment of a Commissioner of Patents, who was required to superintend and perform all duties touching the granting of patents. The conditions under which an applicant was to be entitled to a patent were substantially the same as under the Act of 1793, except that foreigners were placed on the same footing as citizens in all particulars, except as to the amount of fees paid. The term for which patents were granted was, as under the previous acts, fourteen years; but an important innovation was introduced in favor of patentees. Provision was made for the extension of a patent upon the expiration of the term for which it was originally granted for a further term of seven years, if it should be made to appear that a patentee had failed, without

neglect or fault on his part, to obtain a reasonable remuneration for the time, ingenuity and expense bestowed upon the invention, having due regard for the public interest. The right to the extension of a patent was taken away by the Act of 1870, by which act also the original term of a patent was made seventeen years.

Another important feature of the patent law introduced by the Act of 1836 was the provision for the registration in the Patent Office of assignments of patents or individual interests therein, and of all grants of exclusive rights to an invention in specified territories. This change gave a security to the title of a patent similar to that given to a title to lands by a registration of deeds.

The most important change, however, introduced by the Act of 1836 was the power given to the Commissioner to decide whether an applicant was entitled to a patent under the provisions of the statute. In discharge of this duty it was incumbent upon him to make, or cause to be made, an examination of the new invention for which a patent was asked. If, on examination, it should appear to him that the invention had not before been made in this country, or that it had not been patented or described in a printed publication, and had not been in public use or on sale with the applicant's consent or allowance prior to the application, the Commissioner should, if he deemed it sufficiently important and useful, issue a patent therefor. No such examination, to be made previous to the issue of the patent, had been called for by the previous acts or by the law of any other country. It has proved to be one of the most valuable and important features of the patent system, and, in one form or another, it has since been provided for by many of the nations which grant patents for inventions.

Under the Act of 1793 a patent was granted to an applicant if he made oath that he believed that he was the first inventor of the invention. If he was mistaken his patent was void when the mistake was shown. It is obvious that in most cases it would be impossible for an inventor to know with certainty what had been done before, and the expense of an examination of the state of the art would be too great for most if not all inventors. Without such examination no purchaser of a patent could feel any assurance that the patent would not prove to have been anticipated, and under the Act of 1836 it was made the duty of the Commissioner of Patents to make the examination which the inventor in most cases could not make himself. The cost of the examination was covered by a fee of $30, which the applicant was required to pay. To provide facility for the examination, the act provided for the establishment of a library of scientific books, and appropriated $1500 for its

acquisition. This library has grown now to contain nearly 60,000 volumes.

It is true that the examination thus provided for was not to be conclusive, and a patent might be found to be invalid notwithstanding the examination. A defendant in a suit has the right to show, and often does show, that a patent is void for want of novelty or invention; but, though the examination is not conclusive and binding upon other persons, it is valuable both to inventors and to the public. The records show that nearly half of the applications for patents which have been made during the past five or six years have been rejected because the supposed inventions were found not to be novel. Under the old practice patents would have issued on all these rejected applications without benefit to the inventor, and to the annoyance of the public. The strong presumption which the examination furnishes that the subject matter of the patent is new, and that the patent is therefore valid, gives a value to it from the moment of its issue which it would not otherwise have, and increases very much the security of the investment of money in it. Very few inventions can be made profitable without a considerable outlay. Few inventors have the necessary money to develop an invention and place it upon the market, and few men who have the money could be induced to invest it in a patented invention except for the confidence which this system of examination gives in the validity of patents.

Another important duty imposed upon the Patent Office by the Act of 1836 was the power to investigate the claims of two or more inventors to the same invention, and decide which was the first inventor. Cases of this kind, known as "interference cases," often arise.

Another important change in the patent law was introduced by the Act of 1839. Under the Act of 1793 the inventor lost his right to a patent if the invention had been known or used by others before he made his application. To avoid the risk of having the invention put into use by some one else, and thus losing it, he was compelled to make his trials in secret. Sometimes the nature of the inventions made this impossible. The Act of 1836 relieved him from the liability to loss from the use of the invention by others *unless* it was with his consent and allowance. But, in order to give an inventor the opportunity to test his invention by actual use without risk of his losing his right to a patent, the Act of 1839 provided that no use of an invention by the public, either with or without the consent of the inventor, should deprive the inventor of his patent unless the use had been made for more than

two years, or upon proof of abandonment. The Act of 1836, with the amendments of 1839, virtually determined the character of the patent law as it exists to-day.

There were no substantial changes in the patent laws after 1839 until 1870, when, as before stated, the term of a patent was changed from fourteen to seventeen years.

Last year the patent laws were again amended in some substantial respects, and the amended law went into effect on January 1, 1898. Before that time the first inventor was entitled to a patent for his invention, provided it had not been in public use or on sale in the United States for more than two years before he filed his application. Under the new law he loses his right to a patent if his invention has been patented abroad, or has been described in any printed publication in this or any country more than two years before his application is filed.

Another provision of the new law relates to the effect which a prior foreign patent has upon a United States patent. Under the old law a patent granted in the United States for an invention previously patented in some other country would expire with the first expiration of a foreign patent. This law sometimes worked great hardship to American inventors in this way. It takes a long time for some cases to secure the allowance and issue of a United States patent, while in many of the foreign countries the patent is granted very soon after the application is filed. The inventor ordinarily desires to exploit his invention in this country as soon as possible, and generally begins to do so, at least, as soon as he files his United States application. The public thereby gained the knowledge of the invention. In some of the foreign countries the laws permit the granting of a valid patent to the first applicant. In England whoever first introduces into the realm the knowledge of the invention is regarded as the inventor, and he is entitled to the patent to the exclusion of the man who originated the invention. Any one, therefore, who learns of an invention in the United States may obtain the patent therefor in England and some other countries if he makes application before the real inventor does.

The American inventor was therefore between the Devil and the deep sea. If he did not apply for his foreign patents until his United States patent was about to issue some stranger might in the meantime apply for such foreign patents, and the real inventor's rights to such patents would be irretrievably lost. Or, if, to prevent the loss of his foreign patents, he applied for them before his United States patent was ready to issue, the foreign patents might be granted first, and that would cut down the term of the United

States patent. To relieve the inventor from this predicament the new law provides, in substance, that a United States patent shall remain in force for seventeen years, provided it is applied for before or within seven months after the first foreign patent is applied for. The law also provides that if the United States patent is not applied for until more than seven months after the first foreign application is filed no valid United States patent shall be granted.

Other changes in the law are under consideration by the Patent Committees of the two Houses of Congress. Fifteen bills of importance, and more than that number which are not important, have been introduced in the House and Senate, and probably some of them, after going through the committees' hands, will come up for action during the present session of Congress. When I began to prepare this paper I intended to refer to the more important bills and thereby to provoke discussion as to their merits, but the consideration of the past and present demanded so much space and time that I was forced to abandon the consideration of the possible future. As it is, the paper is longer than I intended to make it, and I feel that I owe you my thanks for your prolonged attention. I will close with a short quotation from one of the annual reports of the Commissioner of Patents:

"The place of the Patent Office among Governmental agencies is as unique as it is important. It is concerned neither with the collection nor the expenditure of the ordinary public revenues. Unobtrusive and unsensational in its work and methods, it asks nothing of the Treasury excepting moneys which its patrons contribute, and nothing of Congress excepting measures to secure its highest efficiency. As it enters upon the second century of the system which it administers the distrust which has existed to some extent of its functions has happily passed away. The triumphs of American invention have attracted universal admiration, and the conspicuous demonstration of their importance and usefulness has turned distrust to confidence. I verily believe that no law or legal system in any age or any land has ever wrought so much wealth, furnished so much labor for human hands or bestowed so much material blessing in every way as the American patent system."

DISCUSSION.

Mr. W. R. Warner.—I should like, from Mr. Thurston, some information respecting the patentability of a combination of a patentable invention with one the patent on which has expired. For instance, plumbers use a small oil torch, about as large as a quart cup, and with a handle on one side, and the patent on this

has expired. This torch gives a hot but non-luminous flame. In the patented Welsbach burner a mantle becomes incandescent by being suspended over such a flame. Now, if these two were combined, making an incandescent oil burner, would the combination be patentable?

MR. THURSTON.—I should say not; but possibly some modification of it might be.

MR. WARNER.—There is an invention which, as I understand it, combines just these features. It gives a light a little more brilliant than the incandescent, and is quite a taking thing, but it forms a combination of two inventions the patents on which have expired.

MR. THURSTON.—In order that anything may be patented it must be new; it must be useful; it must be something invented, in contradistinction to the work of an artisan or workman. Such a combination as Mr. Warner has mentioned could be made by any one.

A combination patent is as good as any other provided the claim does not contain superfluous elements, without which the same result might be obtained. A combination embraces a number of elements, all of which co-operate to secure a certain result; but if these elements in the combination do just what they did separately, and no more, the combination is called an aggregation, and is not patentable.

MR. OSBORN.—What I understand to be the combination mentioned by Mr. Warner is now in use in Belgium. It is claimed that it is patented here.

MR. THURSTON.—It might be patentable, and yet the patent might have no scope.

MR. J. C. BEARDSLEY.—May not a new application of an old idea be patented, or a combination of two old ideas, forming a new one?

MR. THURSTON.—One of the principal maxims of the patent law is that the new use of an old thing is not patentable. If the old things, combined in a new structure, co-operate and form a combination, that combination is patentable.

MR. N. P. BOWLER.—The Westinghouse air brake is made up of four devices, and these all co-operate, forming a patentable combination.

Thomas Jefferson had more to do than any one else in enacting such laws as he liked in reference to patents. He considered a patent as a contract between the Government and the patentee. He scanned the patent applications very closely, and but few

patents were issued. But the late courts have decided that a patent is not a contract, but a right or privilege given by the Government to the patentee.

The first Patent Commissioner was also Commissioner of Agriculture, and gave more time and attention in his report to agriculture than to mechanism.

Mr. J. C. Beardsley.—Why does not the principle of aggregation apply to the chainless bicycle?

Mr. Thurston.—I think it does. There are no patents of any scope on the chainless bicycle. Every one of them is limited.

Mr. C. O. Palmer.—I understand that in order to have a combination the parts, taken together, must produce a new and useful result, and must co-operate.

Mr. Thurston.—The parts must co-operate, but they need not produce a new result. A new combination producing an old result is patentable.

Mr. Palmer.—Patents and copyrights constitute property in ideas, and this, I believe, is not the case with anything else.

Mr. Wm. E. Reed.—I understand that in some countries an additional fee is charged. I would ask Mr. Thurston what he thinks of this requirement, and whether it would act as a restriction or as an aid.

Mr. Thurston.—In this country the tendency seems to be to make the patent cost as little as possible to the inventor. In Canada he must pay $20 every six years. In this country a curious law has been proposed, under which any inventor can secure a patent without paying any fees whatever, if he will dedicate his invention to the public.

Mr. Palmer.—If the elements of a claim are used in a manner wholly different from that intended by the inventor and contemplated in the specifications, would such use constitute an infringement?

Mr. Thurston.—The inventor is entitled to protection only on the thing he invents, but he is entitled to protection on all the uses to which that thing can be put; and if the same combination of parts covered by the patent is put to different uses, even to produce a result which the inventor never intended, that may be an infringement. He is entitled to such protection even though he do not ask for it.

LEVEES, WITH SPECIAL REFERENCE TO THE RED RIVER SYSTEM.

By Frank M. Kerr, Member of the Louisiana Engineering Society.

[Read before the Society, April 11, 1898.*]

To begin with there is no "Red River System" yet. Many miles of levees, involving a vast amount of earthwork and costing large sums of money, have been built, in more or less continuous stretches, along certain parts of Red River, where, as a protection against overflow to rich and fertile sections of country, their maintenance has proved, by experience, to be of prime necessity. But the results so far attained, though encouraging and assuring, cannot yet well be dignified by the name of system.

The term system, to my understanding, implies such a combination or successful assemblage of co-ordinate principles as will evolve a scientific and complete whole. What has so far been accomplished on Red River in the way of a levee system is yet far from any such proud consummation of design and effect. In fact, science has so far had little, if anything, to do with it. Necessity, the mother of invention, earnest effort to accomplish the greatest good for the greatest number, cutting the garment to fit the cloth, and a general admixture of main strength and awkwardness, now and then, have so far formed the mainsprings of action in the premises.

To introduce the subject before us in accordance with approved methods, requires me, I presume, to touch first upon the geographical position of Red River, and then to depict to some extent its general features.

By reference to almost any authority on such subjects we learn that the Red River of the South has its source in a ravine at the eastern rim of the Llano Estacado, in the Panhandle of Northern Texas, and flows, first, in a general easterly direction, forming the boundary between Oklahoma, Indian Territory, and Arkansas on the north, and Texas on the south. Then, upon entering the State of Arkansas, about ten miles north of Texarkana, and reaching Fulton, Arkansas, it changes its course to a general southerly direction, down to Shreveport, La. Below Shreveport another change to a general southeasterly direction occurs, which is main-

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tained to its junction with the Mississippi River, through Old River, around Turnbull's Island, formed by a cut-off in the Mississippi River, in days gone by, just above Red River Landing, in Pointe Coupee Parish.

The ravine in which Red River rises is some sixty miles in length, its walls, composed of sandstone, ascending precipitously from the banks of the river to heights of 500 and 800 feet. The bluffs through which this ravine has in time worn itself rise abruptly from the prairie, and terminate in a barren plateau, stretching to the south and west. After leaving the Llano Estacado the river spreads out into a shallow stream, from a quarter to a half a mile in width, its waters flowing swiftly over a sandy bed. This feature of the stream varies but little until it reaches the point where it is joined by the Wachita River of Oklahoma and Indian Territory. Below this the change is radical, the river meandering, with greatly varying width and depth, from point to point, through rich alluvial bottoms.

The basin of Red River is the smallest of the great basins influencing conditions in the Mississippi Valley, covering only about 90,000 square miles, but the rainfall which it receives at times is equal to the highest of record anywhere, and, on occasion, certain localities in the basin are visited by periods of phenomenal precipitation.

The Red River so far described is some 1200 miles in length. That part of it, however, with which I can claim any degree of familiarity, I cannot say knowledge, extends only through what may be termed the northwestern quarter of our state, a length of river of about 395 miles.

This part of Red River, that is our Red River in Louisiana, presents in its length, from time to time, many greatly differing features and conditions; but, for the purpose of this cursory article on the subject, we may limit any subdivision of contrast in its characteristics to what may be called the upper and lower half of the river, the line of demarkation being in the vicinity of Montgomery.

The upper half of this river is, to a large extent, tortuous to a fault. For many miles, on different parts of its length, bend after bend follows in close succession, the one after the other; so that it is not uncommon for a boat, traveling up or down the river, to appear many times in the same field of view, or line of sight.

Along this upper half of the river, too, the section is extremely variable, and the slope steep and irregular; so that during periods of high water the flow of the stream, while always swift, is

frequently subjected to severe shocks, the river thus, from time to time, in its course, changing from a placid stream to one of almost torrential aspect. To partly illustrate this latter statement let us look at the slope of the river during the last two extreme high waters in the upper Red River of Louisiana. These two waters were practically of about the same volume, and delivered under about the same conditions, except as to confinement, the latter being held under much better control than the former. From the State line to Alban's Canal, No. 1, a distance of 12 miles, the slope of 1892 was 0.17 per mile, in 1894, 0.28 per mile; Alban's Canal, No. 1, to Red Bayou, 5.2 miles, in 1892, 0.81 per mile, 1894, 0.32; Red Bayou to Wild Lucia, 12 miles, in 1892, 0.70 per mile, in 1894, 0.46; Wild Lucia to Cottonwood Bayou, 9.4 miles, in 1892, 0.87 per mile, in 1894, 1.07 per mile; Cottonwood Bayou to Eric's, 7.6 miles, in 1892, 0.60 per mile, in 1894, 0.92; Eric's to Pandora Bend, 13.2 miles, in 1892, 0.24 per mile, in 1894, 0.42; Pandora Bend to Shreveport, 9.4 miles, in 1892, 0.68 per mile, in 1894, 0.48; Shreveport to Knox Point, 36.3 miles, in 1892, 0.61 per mile, in 1894, 0.57; Knox Point to Loggy Bayou, 27.1 miles, in 1892, 0.29 per mile, and in 1894, 0.51. The lengths of river thus referred to are those included in the partly leveed portions of the Caddo and Bossier Levee Districts, and similar irregularities in the high water slope of the river prevail in other parts of it.

Tortuous in direction, as stated before, its banks friable and sensible to friction, and its bed in many places trammelled with obstructions, causing violent disturbances, it is, therefore, not surprising that erosion of its banks is common, and any number of concave bends exist in which caving is extensive. Cut-offs, too, often occur, again tending to disturb conditions to the detriment of the regimen of the stream.

I suppose most of us know what cut-offs are, but for those who may not I will try to describe what they are and how they are brought about.

When the sides of two bends, forming a point of land on the river, are affected by caving, the result is the narrowing of the space separating the stream between the points of attack, until a neck is formed, which, with a continuance of adverse conditions, grows thinner and thinner, until the neck is finally worn through, causing a breach, or cut-off, through which the river forces its way, abandoning its longer and consequently flatter course for the shorter and temporarily steeper one. Numbers of these cut-offs have occurred in Red River, and have no doubt, between given

points, materially lessened the length of the river in its many years of existence.

The lower half of the Red River with which we are dealing is generally less tortuous than the other half, its section larger, and its general conditions more stable. What the lower half has, however, gained over the upper half in these respects, it has largely lost in others, principally in wasted energy, affecting more directly navigation, during periods of low water, than the subject we have at present particularly in mind.

The main tributaries of Red River enter above our State line from Oklahoma, Indian Territory, Arkansas and Texas. In fact, after entering the State of Louisiana it cannot be said to have any tributaries of any moment, in the broader sense of the word, until it is joined by Black River, only about thirty-three miles above its mouth.

It is true that, at times, a chain of lakes carries the drainage of a considerable area of country, lying between Jefferson, Texas, and Shreveport, La., into Red River, through Twelve-mile Bayou and Cross Bayou, just above Shreveport, returning also through the same channels, and to the great detriment of Red River, quite a volume of overflow water which escapes from the main river, through an unleveed portion of its banks, some eight miles in extent, about three miles below the State line; that Loggy Bayou, at times, also pours into it quite a volume of drainage water from the Lake Bisteneau region, below Minden, La.; that Bayou Pierre, under certain conditions, also tends, at its lower end, to swell the proportions of Red River to a considerable extent, but these are not by any means the sources of supply from which its high waters come, and oftener furnish escapes of considerable proportions for high water rather than appreciable additions at any time to its volume, except locally.

There have been numerous lapses in the continuity of both of the banks of Red River, but with very few exceptions and at odd times these openings have been outlets from and not inlets into the river, and nearly all of these are now closed by levees.

Some two or three of these may never be closed, as they are located at the extreme lower ends of small basins, and their closure would interrupt the drainage of these areas, now permitted during periods of low water in Red River, except by means of extensive and costly pumping plants.

As to its name, Red River, it is derived from the color of its bed and waters. Of course, its bed is not a decided red throughout its section and length, nor are its waters so at all seasons of

the year; but with shades varying from deep carnelian to dull Indian red, contrasted now and then with strata of white sand and pockets of yellow ochrous earth or clay, the general tone of the whole is always sufficiently decided to justify the appellation. The intensity of color in its waters is, of course, proportionate to the amount of red silt carried, which varies greatly with the seasons, the volume of water in motion, and the ability of the stream to retain the silt in suspension.

In reflecting about Red River I cannot help picturing to my mind three very distinct and greatly differing rivers, one of the past, mostly traditional, an octopian affair, reaching out in all directions with innumerable feelers to prey upon the valley; one of to-day, a very much matter of fact affair, largely impressed by force with a sensible appreciation of bounds and of the rights of others; and lastly, one of the future, when by continuous proper treatment and permanent control it may be "a thing of beauty and a joy forever."

The Red River of the past was a stream of spasmodic effort, erratic character and willful tendencies. Its channel, from time to time, shifted pretty much all over the northwestern quarter of the State. In periods of flood it practically occupied the whole of the valley, and at certain stages of such periods, as well as during minor freshets, it bore upon its bosom vast quantities of drift of all descriptions, and parts of this, lodging here and there, formed jams in channels of previous passage, forcing the next flood waters, freighted anew with drift, to find other routes, in many of which jams were again formed, diverting the waters again and again. In this way a vast network of streams, active and passive, was created in the valley of Red River. These channels, following the tendency of water, like all things animate, to attack that which most readily yields, to travel the smooth rather than the rugged path, to run down rather than up hill, were also very sinuous. To such an extent was this the case, and so numerous were these devious outlets that their bends were often in such close juxtaposition that when the floods came rushing broadcast down the valley, they readily broke one into the other, forming cut-off upon cut-off, abandoning their former beds in the bends and leaving them here and there in the form of odd-shaped lakes. In this way we find evidences of the wanderings of Red River from the State line to the lakes of the Atchafalaya River region, and for miles and miles east and west of the main stream.

One of the most prominent features of this period of Red River's struggle for right of way, and its arch-enemy to progress,

then and for many years after, to an appreciable degree even as late as 1885, was the great raft, extending at one time and then another from a point some fifty miles above Shreveport down as far as Grand Ecore, and even somewhat lower, at one time, probably, covering a length of river of upwards of 200 miles.

Of course the raft did not consist of one continuous jam for this entire distance, but compact jams of large proportions and many miles in length occurred at intervals, with stretches of clear channel between. So great was the obstruction wherever this raft existed that passageway by water could only be had by lateral outlets and canals around the raft, connecting the pools of water in the main bed of the river.

In addition to the visible raft in the bed of the main stream and of its outlets, the caving banks, and the lowering of the low water line in the river which has occurred in late years, demonstrate that a very large part of the alluvial soil of the valley rests upon a vast raft of timber arrested in its flight to the sea in ages past. As the banks in many places cave into the river, great trees project out into the stream in innumerable numbers, and as the low water line goes down drift heaps and forests of stumps come constantly to the surface.

Not all this buried timber and upright trees and stumps is, however, due to drift, borne from higher latitudes; much of it is of purely local origin, having grown just where it was found, and having been alternately covered by alluvium and then exposed again by the shifting of the river bed in the effort of its waters to get around and past obstructions.

The next great obstruction in Red River is the falls at Alexandria, 117 miles above the mouth of the river. They are a relic of the past, still very much in evidence to-day. This obstruction, however, concerns more particularly than any other the problem of navigation during periods of low water. The falls cover a stretch of something like half a mile in length, occupying in their length the entire bed of the river. They have a drop of about three feet, at low water, above Bayou Rapids, with two rapids some little distance above having a drop of about one foot.

The rock forming the bed of the river at the falls consists of an extremely soft and friable sandstone slightly impregnated with marl.

Various methods to overcome this obstruction have been proposed,—namely, to build a lock and dig a canal around the falls; to open and enlarge Bayou Rapids; to remove the falls or cut a channel through the rocks, and to contract the water way by wing

dams. Of all of these methods that of removing the falls naturally meets with most favor, and the only attempts so far made to improve them have been in that direction by cutting away a portion of the top, and also by cutting a narrow channel through the rocks.

During the latter part of the "late unpleasantness" between the North and the South the Federal fleet, operating with the army on Red River, was caught by low water above the falls, and extricated from a most perilous position by an engineer of the army corps, named Bailey, who built a dam across the lower falls, and wing dams upon the upper, locking the water over the falls, where he concentrated the fleet, and at a given time opened the dam and rushed it through the gap.

Very much the same method, on a very much smaller scale, of course, is, during periods of extreme low water, often resorted to by steamboat men to wash out a channel through and deepen the water over sand bars which exist in quite a number of localities where the carrying capacity of the river has been impaired by local conditions.

The removal of the falls is opposed by some on the grounds that it would involve still greater danger to navigation above by permitting too great an escape of water at low stages, claiming that the obstruction acts like a dam and retains a depth of water in the river above that could not otherwise be expected. But Red River being a sediment-bearing stream, the check given to its current by the back water from the falls must tend to cause deposit over the entire distance of retardation, and it is more than probable that the effect of the falls is to gradually shoal rather than to deepen the water above. The removal of the obstruction should, on the contrary, so increase the slope and current as to wash out the alluvial deposits.

The Red River of the past, during periods of great floods, as stated before, occupied practically the whole of its alluvial valley, except, possibly, a narrow strip of land probably not more than a hundred yards or so in width, forming the banks proper of the main stream.

As we all know, the greatest deposit of sedimentary matter occurs where the velocity of the stream carrying it in suspension is first interrupted; so that when the water in such a stream rises to an elevation overtopping its banks a continuous line of interruption corresponding in direction to the course of the bank follows, and here the first and greatest accretion from deposit is made, year after year, the land next to the river receiving less and less

deposit in proportion to its remoteness and the amount of obstruction encountered, until a point is reached inland, usually in the swamps, where practically only clear water prevails, except in special cases influenced by local conditions. In this way the banks proper of all streams, large and small, in the valleys of sediment-bearing rivers, like Red River, are higher than the contiguous country, the land sloping generally from and not toward the stream.

All but this ribbon of bank, and a high plateau here, a group of hills there, or a bluff now and then, was hidden beneath the surface of the floods characterizing the history of the Red River of the past.

The Red River of to-day, and it is with it that we are most concerned, may, in my mind, be reckoned as a shining example of the survival of the fittest. It is still more or less in a state of transition and is not yet, through all its length, an ideal stream by any means, but for the better part of its length it certainly now follows a fairly well-defined course, as compared with the past, governed here and there by levees, and, at intervals, by its natural banks, rising, with varying margins, above the general plane of high water. And here let me direct attention to the fact that along those parts of Red River where the natural banks have, within the memory of man, been above high water, and unbroken by outlets, the channel is practically free from obstruction and the high water plane of one flood stage presents little if any violent contrast to that of another of equal proportions. In fact, the natural banks perform the same good offices there that the levees do on the other less favored parts of the river.

This conversion of the Red River of to-day from a bad to a better state is being brought about not by any self-imposed sense of duty and right on the part of nature, but by control, and consequent development.

This control is being effected through channel work by the United States Government, and levee building by individuals, the State and the Levee Districts; and the development of the stream which is following is the Q. E. D. of the principles embodied in the treatment.

The channel work so far prosecuted by the United States Government has been principally in the nature of removing rafts, jams, snags, wrecks, leaning and projecting trees, etc., and, latterly, in assisting the local authorities to some extent in building levees, recognizing that the confinement of the waters of the river to one main channel was a prime factor in ultimately securing the rectifi-

cation of the river for purposes of navigation, as well as for relief from overflow. The recommendations of the engineers of the United States Government annually urge larger appropriations for the purpose of levee building, revetting banks and constructing jetty walls, to reduce the width of the river and restore its energy where bays out of proportion to the generally required section of the stream exist.

Of course in the earlier days of Red River, when its population was small, and its general conditions, material and social, were primitive, overflows were not affairs of such serious consideration as in the present day when the valley is alive with humanity and teeming with its world of interests. Those who occupied the valley in its earlier days improved and cultivated only the high banks next to the river; that is, the narrow strip which, except in very extreme floods, remained above water, as before explained. But, as time went on, reports of the prosperity of its settlers, in spite of their struggle with floods, spread beyond the confines of the valley, and it became invaded year by year by new promoters in agricultural and commercial pursuits, until all the front lands were taken up, and attention was per force directed to the back lands, which were annually submerged many feet deep by high water.

First, some outlet from the main stream was closed by parties in immediate local interest to limit to a certain extent the period of direct submergence from the river. Then the line was in time extended, here and there, over low banks, until after many years the work passed beyond the compass of individual ability. Then followed, spasmodically and sparingly, State aid. In this way, by individual effort and limited assistance from the State, many detached lines and stretches of levee, of uncertain location and dimensions, were built along parts of Red River. The partial success of these tentative barriers against overflow finally suggested bolder and better steps, resulting in the organization of levee districts with boards of local commissioners empowered to raise revenues to devise plans for and to build and maintain comprehensive levee systems for the east and west banks of the river, from the State line to the lower limits of the parishes of Caddo and Bossier, and the west bank from Alexandria to the Avoyelles Prairies.

The principles involved in the construction of levees on Red River do not differ materially, if at all, from those in practice for levees elsewhere. To get them high enough to afford a reasonable sense of security against being overtopped by succeeding floods, and wide enough at the crown and base to include a section of

earth sufficient to resist pressure with some degree of certainty have so far constituted the main parts of the formulæ governing their dimensions. In this way an embankment averaging generally three feet above the water of highest local record, with a crown six feet wide and a base equal to six times the height plus the width of crown, and banquettes of prescribed widths and heights where the levee crosses depressions much in contrast with the general surface being leveed, has been erected in the Caddo Levee District, from Blanton's Bluff, Ark., to the lower side of Sale and Murphy Canal, a length of levee line down Red River of 3 miles; from a point about 3 miles above Red Bayou to Hurricane Bluff Plantation, 22.5 miles; from the upper side of Bayou Pierre to the upper side of Tones Bayou, 12.5 miles; from a point on Bayou Pierre 9 miles below Tone's Bayou to the lower limit of the parish of Caddo, a length of line up Bayou Pierre and Tone's Bayou and down Red River of 36 miles. This aggregates a length of levee of 74 miles, leaving gaps in the line from Sale and Murphy Canal to about Hervey's Slough, Hurricane Bluff Plantation to Shreveport (except some little levee work of extremely small dimensions by private individuals), and at Tone's Bayou, aggregating about 35 miles.

In the Bossier Levee District a continuous line of about the same character extends from Hurricane Bluff to the Buckhorn Plantation, a distance of about 55 miles by the levee line, leaving only about 12 miles of the district at the lower end unleveed.

The levee line in the Red River, Atchafalaya and Bayou Boeuf Levee District on Red River begins at a point on Bayou Rapides about 2.5 miles above Alexandria and extends to Laborde's on Red River, about a mile above Bayou Choctaw, which is just above the Avoyelles Prairies. The length of this line is 37.5 miles.

Of course this does not constitute all the levees on Red River in Louisiana,—only those in the incorporated districts,—for there are many detached dikes, closing outlet bayous and short stretches of levee in a number of localities important only to the individual, or small communities, protecting territory too small to form part of a general system, or not yet incorporated in levee districts engaged in the establishment of public systems.

To ultimately perfect the system in view and reduce the chances of accident, to which it may be subjected, to a minimum, much thought has yet to be given to extension, location, grade and section.

In a river so sinuous as Red River, and one started on such a

career of development, as in the upper half especially, locations possessing anything like a fair tenure of life must ever be difficult and uncertain, until all parts of the stream have developed in section sufficiently to perform the work with which the river is charged, and those parts of it which cannot recognize when they are large enough and those which persist in surrendering to caving are regulated and made stable by revetment.

For many a day to come will it be the same on Red River; the only possible chance for safety in a line of levee against caving banks lies in distance, many of the lines located within the past six years, from 500 to 1000 feet from the bank, being already threatened at an early day by encroaching river banks. The extent to which the improvement in the grades and sections of the levees in the Caddo and Bossier Levee Districts must eventually be carried is still more or less uncertain. But from such observations as have so far been permitted it is not too bold to venture the assertion that the grades to which it has so far been possible to build them in these two districts will, for the most part, prove fairly sufficient against any such floods as have so far visited the valley, except possibly on certain stretches of the river where its development has not yet reached as promising a stage as on others; while in the Red River, Atchafalaya and Bayou Boeuf Districts it may be unhesitatingly said that a good margin of safety for its levees on Red River against future floods has been reached if properly cared for and maintained.

For a long time it appeared to the greater number of the people on Red River that the only chance of exemption from the disasters of overflow rested in each one having the crown of his own particular line of levee somewhat higher than that of his vis-à-vis, on the opposite side of the river, and to back up the theory with a shotgun during the period of high water. But that kind of sentiment has now passed, thanks to more and better levees.

I have several times referred to the development of Red River, which no doubt demands some illustration. I doubt if there exists anywhere any instance of enlargement in width, and increase in depth, due to successful confinement, that can compare with what has occurred on the upper half of Red River in Louisiana. A glance at the blue print of that part of Red River known heretofore as "Little River," accompanying this paper, will show you a contrast between the size of the river before and since channel improvement and confinement by levees that cannot well be improved upon nor gainsaid. To further illustrate this fact, I cannot do better than quote from the report, for 1894, of Major J. H.

Willard, Corps of Engineers, U. S. A., in charge of internal improvements on Red River, viz.:

"The bottom of Red River in the raft region above Shreveport has gone down as much as fifteen feet, the low water line following it to a certain extent, and a similar process has been going on below, especially in the stretch known as Little River. The effect has been to lower the general low water limit, increase the depth and give a greater carrying power to the whole river. It might be expected that the high water line should follow the general improvement, but the development of the valley, denuding it of timber and the accompanying reclamation of lands by drainage, have changed the conditions to such a degree that the rainfall is no longer held back to filter through the soil or drain slowly into the river, but it is precipitated into it with a rush, so that while the total flow may be about the same one year with another, the amount discharged per second in time of flood is far greater than formerly.

"A high water of 35 feet on the Shreveport gauge now means a volume of discharge that could not have been carried by the river in 1849, 1866 or 1874, noted high water years that old settlers refer to. One has only to examine the old channels now cut off, like Lattier, to judge how inadequate the section of discharge would have been even for a flood of far less volume than those of recent years. The abandoned channels have not changed, except perhaps to widen slightly from the wash of local rains; certainly they have not closed in, as may be judged by large old trees that mark the opposite banks; but they look so small as compared with the main river that it seems hard to believe that they once formed part of it and were navigable at certain stages by the large side-wheel boats of those days.

"The gradual closing of outlets and the building up of the levee system, now fully under way, must combine with the speedier delivery of the rainfall to keep the high water line up until the river shall have scoured a channel large enough to carry it, and then we may expect a gradual reduction of flood heights, provided means are taken in time to prevent waste of energy in caving banks and consequently diminishing the slope below a proper working limit."

My personal observation is that the low water line at Shreveport has dropped from two-tenths of a foot below the zero of the gauge in 1890, to five and a half feet below the zero of the gauge in 1894. During all these years navigation on Red River, such as it is in periods of extreme low water, was as good as, if not better than the years preceding, when the low water line was above the zero of the gauge,—in some years as much as three feet,—and what was true of the years here cited has been equally so for the years which have since followed.

High water is not of annual occurrence on Red River. Sometimes as many as four and five years elapse without high water of any moment. Nor is the period of high water on Red River very long, rarely exceeding a fortnight; but then again as many as four serious freshets have been known to occur within one year.

The principal reason for the long periods between extreme high waters on Red River, which so often occur, is due to the fact that there is during most years a striking contrast between the precipitation in the upper and lower portions of the basin.

The precipitation in the lower portion is, in the greater number of years, largely in excess of that of the upper. But in some years this upper portion is visited by heavy rains, swelling all its streams to large proportions, and pouring a vast volume of water into Red River. When this occurs at one and the same time as the annual heavy precipitation common to the lower portion of the basin, then the whole length of the river is tested to its utmost capacity, but when it has only the rainfall of the lower portion of the basin to contend with, as is most often the rule, its ability to dispose of its burden is but little tested.

On the lower portion of Red River, too, that is that part of the lower portion between Alexandria and the mouth of the river, the stage to which high water may rise is appreciably influenced by the stage of the water in the Mississippi River.

In building levees on Red River considerable care has of late years been given to details.

Stripped of some of its verbiage, and rearranged so as to illustrate that which, under any circumstances, is obligatory, that which is required unless otherwise directed, and that which must be done only when directed, the specification prescribing the mode and manner of constructing the levees on Red River reads as follows: First, things which must be observed, under any circumstances,—namely, the removal of all trees, stumps, logs, roots, stalks, weeds, grass, trash and perishable matter of every kind, over the entire surface to be covered by the levee; the plowing or spading up of the ground to be covered by the levee; the grubbing up by the roots of all trees coming within the base of the levee, and for a distance of three feet on either side of the base; the excavation of all buried logs, brick walls and other unsuitable material; the cleaning and filling of all cross ditches for twenty feet from the base of the levee, on the land side, to the edge of the berme on the river side, except where banquettes are made on the land side; the slashing of all trees, in woodland, within 100 feet of the base of the levee; leaving traverses as prescribed, across borrow-pits, with connecting ditches, and planting the entire surface of the completed levee with living roots of Bermuda grass, not more than one foot apart; second, things which must be observed, unless otherwise directed; the cutting to the level of the ground of all trees and stumps within twenty-five feet of the base of the levee on the land side; using earth only in the construction of the levee; obtaining it all from the river side and not disturbing the ground on the land side; shaping borrow-pits with slope, depth, etc.; and leaving all existing levees and parts of old levees undisturbed;

third, things which must be observed only when directed; cutting muck ditches, as directed; completing the clearing, grubbing, preparation of base, and cutting and refilling of muck ditches throughout the whole line or any part thereof before the levee is begun; cutting down trees in open land coming within 100 feet of the levee; placing earth in layers the full width of the embankment, and of thicknesses as directed; cutting openings through the old levees as directed, and digging drainage ditches on the land side of the levee, as may be directed.

The greater part of this specification explains itself, but the purpose for which a muck ditch is dug is not generally understood. As generally required it is a muck ditch only when the levee is built with scrapers and mules, inasmuch as the animals tramping over the fresh earth in the ditch tamp it down. It is probably misnamed, and should more properly be called a search ditch, for it is more generally required for the purpose of exposing any underlying defects within certain limits of the surface of the ground. Very often a most promising exterior soil covers a multitude of sins in the way of defects, such as stumps, logs and cavities. By digging a ditch, which is usually located near the center line of the levee, the presence of any of these defects to any serious degree is made known and the proper remedy is applied.

Another matter of importance in building these levees is the additional height required to provide for shrinkage. Of course the shrinkage of earth taken from pits and placed in embankment varies with different soils and the methods employed in handling them, but to insure a reasonably safe margin under any conditions of soil or method and manner of handling, the contracts for levee work on Red River have so far uniformly required that all embankments be built to a gross height one-fifth higher than the net fill established, and as the soil on Red River is generally of a sandy character and it has almost entirely been handled with scrapers and mules a large part of the line, in consequence, really stands higher than the grade generally spoken of in referring to the levees.

Once properly built and turfed the levees on Red River are less subject to accident from internal causes than almost anywhere else in the state. First of all the crayfish does not exist along its banks. Nor have I ever heard of the muskrat up there. Moles do show up now and then, but they do not disturb the embankment to any appreciable extent, simply skimming along near the surface. On the upper half of Red River, that is in the Caddo and Bossier Levee Districts, I have been shown deep holes bored hori-

zontally into the slope of the levee by the kingfisher, which might be a source of danger in high water if extending any way nearly through the embankment. And on the lower half of Red River, that is in the Red River, Atchafalaya and Bayou Boeuf Levee District, I have seen numbers of a species of mole, locally called a salamander, that can do serious injury to a levee. It is an animal about the size of an ordinary rat, the head closely resembling the rat, with keen round eyes. The foreshoulders and legs or arms are much more developed than its hind quarters and legs, and the forearms are provided with highly developed hands and long, sharp and strong claws. These it uses for digging. Another feature of the animal are a species of bags or pockets of skin just back of its ears. It digs rapidly with the hands, filling the bags or pockets with loose earth, "turns a somersault" in the tunnel it is digging, as graphically insisted upon by a local describer, carries its load to the surface and deposits it at the mouth of the opening, where gradually a small mound of loose earth is reared, by which the presence of the animal and his work is detected.

From one end of the river to the other, however, the hog finds special temptation in the levees, which he proceeds, whenever and wherever he can possibly get at them, to sample with vim and gusto. There are sweeping laws, however, against him, which, on some parts of the river, have been enforced and have summarily disposed of him and his depredations, and it will not be long before its enforcement will extend to all the other parts of the river.

In some localities travel upon and crossing over the levees are the next great abuses to which the levees are subjected, often affecting their integrity. There is, however, much law, too, on this subject, and it is to be hoped that sooner or later a just appreciation of the value of levees to them will lead communities to closely observe all these laws and force others to observe them.

As in most other communities in Louisiana great apathy in regard to levees exists among the people during the period of low water, or as long as the river gives promise of remaining within its banks; but let advices show that the river is about to assume threatening proportions, and the levees become at once their all-absorbing care, and they "hustle" around to the exclusion of all other interests to get them in proper shape. Let a crevasse occur, however, and no attempt is ever made to close it, if of any extent at all, while the water is up. The period of overflow is generally too short to warrant the undertaking.

Finally, as the hour is growing late and we are approaching

the borders of dreamland, and may permit some sway to fancy, a word or two for the Red River of the future.

The Red River of the future may be all that no one ever dreamed of the Red River of the past becoming, and that the Red River of to-day is still far from being. It can be made a stream of stable banks, ample and uniform section, gentle and regular slope, and graceful contour. Its insufficiencies can be supplied and its excesses moderated. It can have an uninterrupted water way trained to follow a given route with all digression from the main channel firmly barred.

Delusive as this may at first blush appear, it is not at all impossible. So much has already been done in some of these directions by comparatively so little when the richness of the field of operation and development and the benefits to be derived are considered that the project should not prove illusive if prosecuted with means, intelligence and vigor. The only question, to my mind is, will it pay? Can the people of the valley be brought to recognize the practicability and value of the work? If so, it will come to pass, and an all levee system with channel work over certain reaches which may be slow, through extremely local causes, to respond to other influences, bank protection and rigorous police laws, local and general, regulating the care, preservation and protection of works of public improvement, will work the miracle. And this all levee system must include the divorcement of Red River from the Mississippi River and its complete merging into the Atchafalaya River.

But, after Rudyard Kipling, I will close by saying "That is another story."

THE CIVIL ENGINEER AS A GUARDIAN OF THE PUBLIC HEALTH.

By J. B. Johnson, Member of the Engineers' Club of St. Louis.

[Read before the Club, November 16, 1898.*]

The sphere of the engineer has rapidly widened with the new applications of scientific knowledge in the promotion of the convenience, the comfort, and the happiness of mankind. The widening of this sphere has also led to a multitude of subdivisions of engineering work, and even the field of civil engineering is often subdivided. But since any civil engineer is liable to be called upon to provide means to promote the general health of the community, I shall here consider the duties of civil engineers as a class in the field of public sanitation.

Sanitary science may be said to have grown along with the science of bacteriology. While Jenner, with vaccination as an antidote for smallpox, in 1798, took the first important step in the way of prevention of disease, the means to be employed for the general avoidance of all kinds of infectious diseases could not have been formulated until the specific causes of these diseases had been found. The proof that all infectious and contagious diseases, together with several not hitherto so considered, such as malarial and intermittent fevers, are caused by taking into the system, either in the air we breathe, in the water we drink, or in the food we eat, pathogenic or disease-producing bacteria, has now been established beyond a peradventure. As soon as this is admitted it becomes somebody's duty to look well to the elimination of these ailments by preventing their causes from reaching their natural prey. On reflection it will be found that the carrying out of these preventive measures devolves largely upon the civil engineer, and furthermore, he is called upon to determine what measures will prove at once most economical and most effective in preventing the spread of these fatal maladies. Our census reports indicate that fully 40 per cent. of all deaths occurring in the United States are from these ordinary germ diseases. These are, in the order of their virulence, consumption, pneumonia, diarrheal diseases, diphtheria, typhoid fever, malarial fever, measles, whooping cough, scarlet fever, and smallpox. It will be noted that these do not include such occasional visitations as cholera and yellow fever, but only those ordinary, every-day diseases which are found with more or less frequency in almost every community.

*Manuscript received December 24, 1898.—Secretary, Ass'n of Eng. Socs.

The tracing of all these species of sickness to the ravages of micro-organisms which are not native to the human body, but which find, in weakened or diseased systems, conditions favorable for their propagation, has created a greater revolution in our lives and is likely to be of far more benefit to the race than Darwin's and Spencer's theory of evolution, or than all other discoveries of this century combined. Second only in importance to these discoveries of the causes of infectious diseases come the various means of prevention which have already been found, most of which it is the business of civil engineers to provide. Now, I hold that if the provision of the preventive means falls within the sphere of duties of the civil engineer, *then it becomes his further duty to thoroughly inform himself as to all these causes and remedies and to lead in the work of educating the public to the point of providing the necessary legislation and funds to carry out such measures and to build such works as are required.*

Here is where the emphasis of this paper lies. I believe civil engineers, as a class, are not sufficiently informed on this subject, and, further, that those who are informed are not sufficiently zealous in leading in the campaign of education required in every community in order to get the necessary acts passed and the funds provided. Engineers are known for their extreme modesty, but modesty becomes culpable neglect when it keeps us from coming forward at any and all times to aid in forming the right kind of public opinion on these subjects.

I wish it distinctly understood that I include myself in this condemnation. We are, I believe, all alike guilty of culpable negligence in this matter. For instance, out of the 1400 active members in the American Public Health Association in 1894 there were listed but 33 engineers, only one of whom was from this city. Practically all the rest were physicians. This is a ratio of 42 physicians to one engineer who are struggling in America with the sanitary problems of the age. It may be that this is about the ratio of the total membership in these two professions in this country, but I should be surprised to learn that the disproportion is so great. As that association is doing a vast amount of good in gathering and disseminating information on this the greatest of all sciences, so far as life and health are concerned, surely it should be better supported by the engineering profession. We should remember that it is the primary duty of physicians to cure disease, whereas it is the primary duty of the sanitary engineer to prevent it. We should expect to see, therefore, a public health association, devoted to the prevention of disease, composed mainly of bacteriol-

ogists and sanitary engineers rather than of physicians. It is greatly to the credit of the medical profession and to the discredit of the engineering profession that the reverse is the case.

Let us now try to evaluate the engineer's responsibilities in these matters. You will all admit that it is solely the engineer's business to provide the drinking water, to dispose of all sewage and garbage wastes, to make healthful streets and alleys and to keep them clean. The business of heating, lighting, and ventilating large assembly halls, hospitals, school buildings, and railway stations and cars is also now coming to be regarded as the business of engineers, and soon the artificial cooling of such buildings will be added to their duties. But the census reports show that one death in every seven is caused either by a diarrheal disease or by typhoid, malarial or intermittent fevers, and nearly all these deaths are known to be caused by impure drinking water. In the year 1890 over 120,000 persons died in the United States of these diseases, and without doubt we may charge this number of deaths to the use of impure water.

It is further shown that the average annual death rate in 1890 from typhoid fever alone was the same in the large cities as in the smaller towns and country, being in both cases an average of 56 in every 100,000 persons. In 1896 this rate had fallen to about 30 in 100,000 in twenty-eight of the leading cities, owing to improvements made in the drinking water in the meantime. Thus the Chicago rate dropped from 83, 160, and 104 per 100,000 in 1890, 1891, and 1892 to 31, 32, and 46 in 1894, 1895, and 1896 respectively. This was traceable directly to bringing into service the water inlet four miles from shore in place of two miles out, which change was made in 1893. That is to say, this change in the intake of the water supply reduced the deaths from typhoid fever in that city during the three years, 1894; 1895, and 1896, from 1856 to 576, or a saving of 1280 lives annually.

If a life is worth $5000, as the laws of many States, including Missouri, have determined, then the money value of the lives saved in these years and since has been over $6,000,000 annually. If to this we add the value of the loss of time by sickness on the part of those attacked by this disease and who recovered, which is usually about six times as many as die, we have a saving of 7680 cases of typhoid sickness. If we estimate a loss of six weeks' time to each patient, and a combined money loss of time and expense of $200 for each case, we have $1,500,000 more to be credited annually to the improvement caused by taking the water from a point two miles further out in the lake.

Again, the city of Lawrence, Mass., had an annual typhoid fever death rate in 1890 of 123 per 100,000, but after the use of filters in 1892 the death rate from this cause fell off to 15 per 100,000 in 1896, or to less than one-fourth the former number.

But even this number of typhoid fatalities is large in comparison with that in many of the cities of Europe. Although in these cities the water is very often taken from very polluted streams, yet it is effectively and intelligently filtered under government regulation and supervision until practically a perfect drinking water results. Thus in 1896 the average annual death rate from typhoid fever in Berlin, Vienna, Hamburg, Munich, Hague, Dresden, Stockholm, Copenhagen, and Breslau was only 5 per 100,000, while the best American average of 16 or 17 could be made up from the cities of New York, Brooklyn, St. Louis, Lawrence and Milwaukee.

There is no American city found in the first class of European cities named above, while Atlanta, Pittsburg, Denver, and Jersey City fell in the lowest class (in 1896) along with (but not so bad as) Alexandria, Cairo, and St. Petersburg. As showing how far behind we are it need only be said that no city in all Germany is allowed to supply an unfiltered surface water to its inhabitants. Even so pure a source of supply as Lake Zurich, at the foot of the Alps, has at times been the source of typhoid fever, and now all the water coming from it for domestic uses is carefully filtered. There is, in fact, no surface water free from contamination either by man or by domestic animals, so that we should immediately adopt the one and only means for purifying these waters for drinking purposes,—viz, sand filtration. Although America has the credit, in the experiments carried out under the Massachusetts State Board of Health, of establishing most clearly the efficiency of sand filtration and the reasons therefor, Europe had long been practicing the method and reaping its practical advantages. On the contrary, while we have fully established the theory of the efficiency of sand filters, we have made little or no progress towards availing ourselves of their benefits. In this, as in many other directions, we are trusting to luck, or to the "genius of American institutions," or to the "hand of destiny" or to some such *ignis fatuus* to bring us along all right without being obliged to plan our lives and to guard the public health by means of these extraordinary precautions which "the effete nations of Europe" find it necessary to take.

While the annual typhoid fever death rate of St. Louis is now only about 20 per 100,000, in 1892-93 it rose to 103 and was con-

sidered epidemic. It is now just a year since a terrible epidemic of typhoid fever raged at St. Charles, Mo.,* *3 per cent. of the entire population being attacked and the death rate being 250 per 100,000 population.* This epidemic was traced to a local contamination of the water supply from their own sewer system,† whereas the St. Louis epidemic was not traced to any local cause. If the same proportion of citizens of this city had been stricken down with typhoid fever we should have had 18,000 cases and over 1500 deaths. What a terrible possibility this is to contemplate! Now, in the case cited at St. Charles, somebody is surely responsible. The sewage contamination was well known to the city engineer, and presumably to the other city officers. The danger arising from such contamination was also well known, or should have been.

As a sequel to a similar epidemic at Ashland, Wis., in 1893-94, a case was tried in the State courts in November, 1897, wherein the company supplying the city with polluted water was held liable for the death of the deceased in the (legal) sum of $5000. I have not heard of this case being reversed‡ by a higher court, and if it should stand it will become a leading case in making the authorities responsible for the lives of the victims of their own negligence.

If a man loses life or limb by falling into an unguarded excavation or into a cellarway on a city street he collects damages from the city. Why should he not obtain damages for disease brought upon him through the culpable negligence of city officials in any other direction? I believe he should, and I also believe we are now ready to make such suits lie against any city or private corporation furnishing polluted water to the citizens. What more right have they to sell to unsuspecting citizens a drinking water

*A town of 7000 inhabitants on the Missouri River a few miles above its mouth.

†See article by Dr. H. H. Vinke in *The Medical News*, July 30, 1898.

‡Since the above was in type, I have learned that the Ashland judgment was reversed in the State Supreme Court, on the ground of contributory negligence. It was shown that it was common knowledge, and had been for months previous, that the water was polluted, and it was further held that the water company was only a carrier. This case would seem to clear a private corporation, but whether or not it would clear a city corporation furnishing water to its own people is another question. The private corporation could be attacked on its contract with the city to furnish pure and wholesome water, in a suit brought either by the city or by a citizen, but as it is a creature of the city government, the city itself would seem to be the proper party to look to for damages for allowing impure water to be furnished to the citizens. The case therefore does not bear the marks of finality.—J. B. J.

containing the seeds of fatal diseases than they have to sell a poisonous drug as a medicinal remedy, or to take life and health in any other way? Evidently they have no more right, and as soon as the state of science becomes such as to make certain to the minds of twelve jurymen that the drinking water was the cause of a death, and that the authorities had been warned and had reason to believe that the water was polluted, and yet continued to supply it, just so soon can the legal compensation be collected by the heirs of the deceased.

When this day arrives it will soon be discovered that preventive means cost a great deal less than the damages will amount to at $5000 per death. And then our cities will be driven to devise the appliances and our city governments to furnish the means for freeing the drinking water from these fatally poisonous germs. But does the conscientious civil engineer who knows, or ought to know, the character of the water he is supplying, and the dangers resulting from its use, propose to sit idly by till he is compelled to act as a means of economy only to avoid legal liability? Such a man should be unworthy of our respect, and yet such is exactly what all we civil engineers in America are doing as a class. One would suppose that as soon as a public official becomes satisfied that he is furnishing a polluted water to the inhabitants over whom he is placed as a guardian in this respect he surely would immediately exert himself to the utmost to have the city water taken from a purer source or purified by an efficient system of filtration. But the accomplishment of either of these ends involves the education of the citizens up to the point of acting in this matter and agreeing to pay the cost of the proposed change. In this country all improvements come from the people themselves, and hence come much more slowly than they do in a country like Germany, where a few men only need be convinced of the necessity of a given measure and it is done. All the more reason, therefore, in this country that the few who do understand the necessity of any proposed change should consider themselves charged with the *duty* of forming and leading public sentiment by all suitable means to hasten the dawn of a better day. And the civil engineer knows, or ought to know, for it is his business to know, the relation between water supply, sewerage, street and alley conditions, the condition of school premises and buildings, and the air conditions in assembly halls, in street and railway cars, in hospitals and in asylums, he knows, I say, the relation of all these to the public health, and, as the construction and operation of all these fall within his professional jurisdiction, he is in duty bound to continually do what he can to teach and lead the public in such matters.

The means of preventing the spread of disease through the drinking water is a rational or scientific filtration, such as has now been shown to be effective. The means of prevention of disease from the decay of organic matter caused by these bacterial parasites, and thence their passing off into the air we breathe, is to immediately remove all organic wastes from the confines of the city. This includes not only sewage or house drainage proper, but all garbage, street sweepings and alley filth, and the prevention of the vast and luxuriant growth on vacant lots of weeds, which are not only the cause of hay fever from their pollen-laden atmosphere, but which, in finally rotting on the ground, breed and give off other swarms of parasite germs to further burden the human system. But the rapid and thorough removal of street accumulations means a smooth, clean and impervious pavement. In place of this we find in this city, in most of the resident districts, either a mud-covered macadam or a rotting wooden reservoir and nest of all possible foulness. I believe there is no possible kind of excuse for a pavement so unsanitary as the wooden block after it has begun to decay. It not only retains nearly all the filth dropping upon it, but it becomes itself alive with those parasitic growths which constitute the decay of timber. Such a pavement is, therefore, the very quintessence of that particular kind of putrefaction and living filth of which we are to-day standing in such awe, and against which we are summoning all the devices of sanitary science. How much the city civil engineer could do if he would to prevent the further use of these abominations!

Again, the most elementary and fundamental principle of sewerage is not only to move all filth off as quickly as possible, but when once it has started it should be kept going till it passes into some large river or goes to some kind of purifying terminus. How do we comply with this provision in this city? In almost every back yard in this entire city will be found a brick privy vault into which the house drainage flows on one side, and out of which it is supposed to flow to the sewers on the other side. It is the most common experience in the world to have these stop up. The near proximity of the coal shed and kindling stall is too great a temptation to the average American child, and sticks, rags, bricks, stones and coals are continually finding their way into these catch-basins and stopping them up. In rented premises the tenant dislikes to go to the expense of having the sewer connection dug up, and commonly the owner will not do it; and so we find that they become filled, and that their contents back up into the house cellars. Often the basins remain in this condition for weeks and even months at a time.

In the report of the St. Louis Health Commissioner for 1895-96 I find that in that one year *over eleven thousand* such cases were found, the vaults being in such a condition as to be declared nuisances, and usually full and overflowing. Probably many times this number of stoppages occurred, only those being reported to the Health Department which were not promptly attended to. These primitive and absurd devices are a remnant of ante-sewer days, when they were earthen vaults or cesspools. When sewers began to be constructed these cesspools were, properly enough, connected with the sewers, but that fact did not justify the further building of them on new premises in sewered districts. And yet this filthy practice has been almost universally followed in this city, and is so to this day, without any protest, so far as I am aware, from the city Sewer Department and without any prohibitory legislation. For engineers to admit that this is the best that can be done is to acknowledge incapacity in this line of sanitary engineering.

Again, in violation of the same fundamental law of sewer construction, namely, the keeping of all sewage moving without hindrance after it is once started, we find in this and in almost every other city, at every street intersection, one or two sewer inlets for storm water and street and alley drainage which are purposely built as catch-basins or as filth depositories. We all know that these are seldom cleaned until they become clogged, and we all know, too, that each of these clogged basins contains a mass of black nastiness which is doubtless swarming with micro-organisms of all sorts, pathogenic amongst the rest. How many tens of thousands of these open pest holes we have in this city I do not know, but I find in the report of the Sewer Commissioner for 1895-96 that 9933 of them required cleaning out and that 16,145 cart loads of filth were taken from them in one year. What is out of sight is out of mind, but if the citizens of this city could but see what lies a few feet below the pavement at every street corner they would raise their hands in holy horror. To claim that these pest holes are necessary in order to keep impediments out of the sewers is, I think, invalid. I would guard these inlets by screens at the surface, and trap them from the escape of sewer gas by flap valves, and so eliminate these catch-basins which, by breeding, harboring, and giving off into the air all kinds of bacterial life, become veritable man traps. Our sewers all have an abundance of slope, and in time of storm will carry along anything that can get into them through properly screened inlets; and if it is not their purpose to carry off the abominations that stop now in these vaults a new

definition will have to be made for them. In my opinion both of these appendages to our sewer system are unnecessary, unsanitary, and uneconomical to such a degree as to warrant their abatement as public nuisances.

And now to return to the question of our drinking water. Since we use a surface water, it is of necessity more or less polluted. All running streams are open sewers in the sense that they drain the tributary watershed and carry all the offal which is removed, in solution or in suspension, by the cleansing rains. The particular character of these polluting ingredients varies constantly from season to season, and from day to day. The general fact, however, remains, to be read of all men, that we take our drinking water from the great sewer of the Mississippi Valley. Not only does it contain its legitimate amount of pollution, but in a year or two there will be added to it, a few miles above our waterworks intake, the offscourings of a city of nearly two million inhabitants, which city lies entirely outside of the Mississippi Valley, and hence is not naturally tributary to it. If it is not good law it ought to be, that in the matter of stream pollution every natural basin should take care of its own, and not change the face of nature to a neighbor's hurt. When the law was enacted for the construction of the Chicago Drainage Canal, the question of the potability of water rested wholly upon a chemical basis. The science of bacteriology was so far in its infancy that it was not yet in use as a tool for sanitary purposes. Now the healthfulness of a drinking water rests wholly upon a biological basis. We now want to know how much life there is in it, and the probable source of this life. As a chemical question we in St. Louis felt that no good case could be made against the scheme. It was then supposed that a running stream purified itself in the course of a few miles, and I see the Secretary of the State Board of Health of Illinois was quoted a few days ago as still holding to this delusion. He ought to know that, so far as the removal of bacterial life is concerned, there is probably not a river in America long enough to purify itself of typhoid fever germs when once charged with them. These germs live for weeks in comparatively pure water, and there is absolutely no possibility of a stream purifying itself from them simply by its flow. If the stream carries a large amount of sediment this is always settling out in the quieter pools along the way, and in this way it is constantly purifying itself, as a clear stream cannot do, since this sedimentation carries down also a large proportion of the micro-organisms. But to claim that they are all carried down in any known distance is to claim what no one knows

to be true, and what would seem to be very improbable from the known persistence of some of these organisms and from the theory of probabilities. In our St. Louis settling basins we do remove a large proportion of these germs, but many remain, and the only way we can remove these is by filtration. If, after settlement in our basins, so much silt still remains in the water that gravity sand filtration is impracticable, then should we not have known this long since? If the filtration of settled water will not remove the bacteria because of the sedimentary removal of those forms of vegetable life which alone can make a sand filter effective, then should we not have known this before now, or at least should we not be finding it out as fast as possible? And if one or both of these causes would make gravity filters impracticable for St. Louis there would still remain mechanical filters to be used with coagulants in conjunction with sedimentation, which, if properly constructed and operated, would doubtless perform the work.

I think a reasonable solution of these problems could be found for a moderate sum, and I believe if we civil engineers as a class, and those of us charged with the administration of the water supply in particular, should unite in demanding that this thing should be done, and done at once, there would be little or no delay. Several years ago Mr. Robt. Moore read a paper before this Club* in which he showed the necessity of filtering our water supply, but our Board of Public Improvement has as yet not moved in the matter. The city Health Commissioner has been crying loudly for years that this should be done, but I cannot find that his hands have been strengthened in any way by our civil engineers, either in or out of the city's employ.

I have tried to show that it is peculiarly the duty of civil engineers to provide clean and sterile streets; to quickly and continuously remove from streets and dwellings all natural refuse and human wastes, and to supply the citizens with an abundance of pure and wholesome water. Also, that when all these things will have been done the cases of sickness and death will be greatly reduced, the average length of life prolonged, and earthly happiness indefinitely increased. Furthermore, that it is peculiarly the duty of all civil engineers to lead in forming a public sentiment which will insure the accomplishment of these results.

I do not wish to imply conscious official or culpable private neglect on the part of any one, but I think we have all as yet declined to take upon ourselves the responsibility which has

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*Journal of the Association of Engineering Societies, Vol. XIV, p. 41, 1895.

recently come to rest upon us, the responsibility of leading public sentiment on these questions instead of waiting till this has crystallized into a particular scheme, and then, when called upon, saying how the thing may be done. Our duties in this respect have entirely changed with the new theory of infectious diseases. He is now the good citizen who foresees what *should* be done and then persuades the people to resolve that it *shall* be done. The man who really *does* it is small and weak in comparison with such a one. Why should not civil engineers be public benefactors as well as public servants?

THE CIVIL ENGINEER AND NATIONAL PUBLIC WORKS.

By Geo. Y. Wisner, Member of the Detroit Engineering Society.

[Read before the Society, December 16, 1898.*]

In April, 1888, a number of distinguished civil engineers, representing twenty-three engineering societies, having a constituency of over three thousand practicing engineers, had a hearing before the United States Senate Committee on Commerce, relative to changes in methods of conducting public works, and, in reply to the statements presented, the chairman of the committee said: "If a worse system than ours can be found on the face of the earth I would like to know it." In view of the fact that strong recommendations have recently been made to have the number of engineer graduates from West Point largely increased, so that an officer of the Engineer Corps can be placed permanently in charge of each river and harbor project, it will be of interest to know whether the statement of the distinguished Senator was true in 1888, and, if so, whether the system of conducting the public works of the country has so improved since that date as to warrant the placing of all important Government engineering projects under the control of graduates of West Point and to exclude all civil engineers from holding any positions on such works except those of a subordinate nature. If the system is worthy of being perpetuated, a fair discussion of its history and merits will give it a higher standing with public men, and, if not worthy, a thorough discussion is certainly desirable.

Previous to the present year the tendency of national progress in this country has been almost entirely along commercial lines, while our system of public works has gradually passed from civil to military control, a condition of affairs which, when compared with the systems of public works of European countries, seems somewhat anomalous.

The continental systems are strictly under civil control, and are so constituted as to secure to the Government the services of civil engineers eminent for their ability and practical experience; and have resulted in the development of men of great theoretical and practical attainments, whose works and writings are the basis of plans of many important public works in this country.

In Great Britain no Government public works organization has ever existed, and, with the exception of dock yards and har-

*Manuscript received December 12, 1898.—Secretary, Ass'n of Eng. Socs.

bors of refuge, all river and harbor improvement works are under the control of boards or trusts, who go into the open market and secure the services of any civil engineers they may choose to select.

The system is one which insures the quick completion of work when once inaugurated, prevents the starting of projects of doubtful utility and completely eliminates all danger of the "log-rolling" methods which have become one of the necessary evils connected with the passage of a river and harbor bill by Congress.

The public works organizations of other European countries are practically similar to those of France and Prussia, which are independent departments of the Government, under the direction of the Minister of Public Works.

Naturally the method of making public improvements in the early days of our republic were those inherited from the mother country, but the limited means at the disposal of corporations and municipalities, and the immense distance over which transportation facilities were required, soon made it necessary to resort to other sources for funds with which to carry on such enterprises. Aside from the Military Academy at West Point, the first engineering school in the United States was established at Troy, N. Y., in 1824, and consequently the source of supply of civil engineers for either public or private work was limited to the West Point graduates and to men who had obtained some experience in engineering as assistants on the few public works then under construction. The decision of the United States Courts at an early date limited State control over navigable waters, and practically settled for the future that the system of public works must be a Governmental one, not necessarily military; and, as the Military Academy at West Point was the only source at that time from which educated engineers could be obtained to take charge of engineering projects, it is not strange that all Government improvements should have been executed under the direction of the military engineers.

The Corps of Engineers owes its origin to an Act of Congress of March 16, 1802, by which the President was authorized to organize and establish at West Point a Corps of Engineers not exceeding twenty in number, which was to constitute a Military Academy, and to be subject at all times to do duty in such places and on such service as the President of the United States should direct.

In 1838 the corps was increased to a total of forty-seven officers, and at the same time a Corps of Topographical Engineers of about the same number was organized. There was but little

harmony in the working of these two organizations, and in 1863 the Corps of Topographical Engineers was abolished and its officers merged into the Corps of Engineers, the number of officers for which was fixed in 1866 as follows: One Chief of Engineers, six Colonels, twelve Lieutenant-Colonels, twenty-four Majors, thirty Captains, twenty-six First and ten Second Lieutenants. This organization was charged with all duties relating to the selection, purchase and survey of sites, and the plan, construction and repair of all fortifications; with all channel and river obstruction for the purpose of defense; with all fixed and movable bridges for the crossing of navigable waterways; with all surveys, plans and construction of harbor and river improvements, and with military and geographical explorations and reconnoissances as might be required for these objects, including the geodetic survey of the Great Lakes.

For twenty-two years after the establishment of this corps the West Point Academy was the only institution in the United States making any pretense at having a course in civil engineering, and it was but natural that the younger graduates of that institution should have regarded themselves as the only ones qualified to discuss problems pertaining to their profession, which opinion, as an inheritance to the graduates of that institution during later years, has probably been the indirect cause of many of their troubles.

In 1843 Prof. Alexander D. Bache, who graduated from West Point in 1825 and soon afterwards resigned from the corps, and from ability and experience having become one of the foremost scientists of the country, was appointed Superintendent of the United States Coast Survey.

Professor Bache was one of the best executive and scientific men of modern times, and Congress, impressed with the business-like methods with which he directed the work assigned to his charge, granted liberal appropriations for its prosecution, with which results of great value to navigation were obtained and a national reputation established for the department. In connection with the topographical and hydrographical survey of our coast lines an accurate geodetic survey was inaugurated, which has since developed into a system of triangulation along the entire Atlantic coast and connecting across the continent to the Pacific Ocean.

The authority granted to the Engineer Corps to make geographical explorations and geodetic surveys soon brought on a conflict with the Coast Survey, which was a discredit to both organizations, and undoubtedly was one of the principal causes for

the distrust with which the methods of conducting our national public works are regarded.

Thousands of dollars were wasted in the duplication of surveys and in the execution of work which has never been utilized, and for doing which there was no apparent reason other than to get ahead of the other department.

The fact that the Superintendent of the Coast Survey was a graduate of West Point naturally gave rise to the expectation that the organizations would work in harmony, but such was far from being the case; and in this connection it is of interest to note that a bitter feeling of antagonism exists in the corps at the present time towards ex-members of that body who have resigned to engage in the private practice of their profession.

With the rapid growth of our country since 1865, and the necessity of securing the best engineering talent available for public works, a general disposition among thoughtful men arose to protest against establishing military supremacy in matters of a purely scientific and civil nature. It was evident that to place our entire national improvements under the control of a close corporation, the members of which were culled from the graduates of a single institution and governed by military rules which prohibited advanced ideas on the part of subordinates, would not be to the best interest of the commercial and other enterprises depending for success on the rapid and economical completion of extensive river and harbor improvements.

The differences of opinion relative to the methods which should be adopted for the improvement of certain rivers and harbors culminated, in January, 1874, in a proposition from Captain James B. Eads to improve the entrance to the Mississippi River for a fixed amount of money, the Government not to be liable for any part of the cost of the improvement unless the results specified should be obtained. A few months later Congress authorized the President to appoint a commission, consisting of three military engineers, three civil engineers and one member of the Coast Survey, to visit the harbors of Europe and report upon the question of the best method of making a deep water entrance to the Mississippi River. This commission decided in favor of the jetty system advocated by Captain Eads, and which he afterwards carried out with such success as to give him a world-wide reputation as one of the ablest hydraulic engineers of the century. If the petty jealousies of some of the older members of the Engineer Corps had not been the controlling element with that body the organization might have secured much of the credit for the success

of the enterprise, and at the same time have advanced their professional standing by securing the cordial co-operation of the civil engineers of the country. Instead of this a bitter antagonism to the enterprise was engendered, which resulted in large financial loss to the contracting engineer and damaged reputations for his opponents. The time never existed when the civil engineers were not willing to cordially co-operate with the army corps, provided they could do so on an equal footing. This right was not admitted, and a struggle for professional recognition by the civil engineers and to prevent loss of control of public works by the army corps has been continued in various ways ever since. While it is to be regretted that so much engineering talent should waste its energies in professional quarrels, certain compensating benefits have resulted, due to the careful studies the advocates of either side have been obliged to give to the plans, methods and projects proposed by their opponents.

The complete failure in 1873 of the plans of the Engineer Corps for improving the entrance to Galveston Harbor resulted in an invitation being extended by the people of Texas, through their Legislature, to Captain Eads to submit a proposition for securing a 30-foot entrance to the harbor for a lump sum, payable when results were obtained.

Captain Eads complied with this request, and a bill was introduced in Congress authorizing the Government to enter into such a contract, but, owing to false representations on the part of the corps to the effect that the Government could complete the improvement for one-tenth of the amount which it was proposed to pay Captain Eads, the bill was defeated.

The work since done on this project has cost nearly as much as was asked by Captain Eads to complete the improvement, and has resulted in securing a narrow channel about 26 feet deep.

With the successful completion of jetty works at the mouth of the Mississippi River, and the general impression that any project for public improvements having its origin outside of the army corps would meet with bitter opposition from that body, many prominent civil engineers were convinced that the good of public service demanded that the entire system should be remodeled, and that civil engineers in such service should be on an equal footing with military engineers as to the control and execution of work under their charge.

At the convention of the American Society of Civil Engineers in St. Louis in 1880 a resolution was adopted to appoint a committee to draft a memorial to Congress asking that the civil

engineers of the country should be placed in full charge of improvement works carried on by the Government. The influx of military engineers into the Society during the next year was somewhat abnormal, and at the next annual convention the committee reported against the contemplated action on the grounds that it would be prejudicial to the interest of some of the members of the Society. A memorial to Congress was, however, circulated privately, to which the signatures of one hundred and sixty-eight engineers were secured, of which sixty were prominent members of the American Society. This was probably pigeonholed and possibly never read in Congress, but the agitation resulted in an invitation being issued by the Civil Engineers' Club of Cleveland to the various engineering societies of the United States to meet in convention, at Cleveland, December 3, 1885.

Ten different societies sent delegates to the convention, and, after formulating a line of action and electing a permanent Executive Board, they adjourned until March 31, 1886, when a permanent organization of delegates from twenty-three societies was effected under the title of "Council of Engineering Societies on National Public Works." A memorial was addressed and presented to the President of the United States, outlining a system by which it was proposed to secure the "adoption and execution of only those projects that are necessary and useful to commerce; the correctness of plans and economy and effectiveness in their execution, and to avoid the wastefulness of public funds in legislation and administration."

After two years of study and discussion the Council of Engineering Societies formulated their conclusions into a bill, which was introduced in both Houses of Congress January 16, 1888. This bill was carefully considered by the committees of both Houses of Congress and favorably reported, but finally died a natural death before being reached on the calendar. Under this bill the military engineers would have had a majority of the officers in the new corps, and no doubt would have controlled its methods to a considerable extent; and as these officers would have been in direct competition with some of the ablest civil engineers of the country the efficiency of the organization of the corps would have been greatly increased. This bill would have become a law but for the lack of support from the technical press, which, for reasons best known to the editors of those journals, did not at that time view the movement with favor.

The discussion of this bill resulted in some changes in the methods of conducting public works which were of much benefit

to the service, but, so far as the military and civil branches of the profession were concerned, the relations were by no means improved. District officers in charge of important enterprises were ordered to give out no information relative to the condition of the works, and to put nothing in their annual reports which could be utilized by civil engineers for the purpose of criticising their methods and plans.

This was carried so far that in one case an assistant engineer who had sufficient self-respect to report the actual condition of the works under his charge was immediately discharged.

The demand for deep water ports on the Gulf Coast was such that several private companies undertook to raise funds by floating bonds with which to execute the work, but were unable to do so owing to the adverse criticism of the projects and plans by the corps. Two of these projects were so near completion before their projectors were obliged to abandon them for want of funds that the results obtained showed conclusively that the completion of the plans would have produced better depth of channel than predicted by the engineers in charge, and yet both of these enterprises have recently been reported on by boards of army engineers as being of no value to the Government, in spite of the fact that vast sums of money were spent under direction of the corps at both of these places before being abandoned by the Government.

One of the worst features of the system is the method of handling the funds appropriated for carrying on national improvements. The clerical work necessary under the regulations is at least five times that which would be used by a good business concern in doing the same amount of business, and, at the same time, does not in any way protect the Government or the public from fraud.

It is true that the army officers are not directly responsible for the regulations under which their accounts are audited, but it is equally true that, by making no protest at the wasteful and unbusiness-like methods required on Government engineering, they become partners to the transaction. The expediency and amount of an expenditure is of little moment compared with the form of the receipt and the color of the ink used. The system is a direct bid for fraud on the part of chief clerks, who become so accustomed to doctoring the form of bills and vouchers for the purpose of having them pass the Treasury auditors that they sometimes forget where to stop. In addition to the expensive and cumbersome office methods necessitated by the system, the engineers in the field are obliged to devote a large amount of valuable time to the supervision of making out and certifying unnecessary bills and receipts.

Probably one of the greatest drawbacks to the success of military supervision on civil work is that military etiquette prohibits all criticism of opinions and plans of ranking officers by subordinates, and it is not at all improbable that the evil effects of this restriction may eventually be the cause of disrupting the corps.

Within the past year one of the most able and brilliant officers of that organization has been tried by court-martial and found guilty of conspiracy and of conduct unbecoming an officer and a gentleman, on evidence which shows that his only crime was in disregarding the red tape regulations of the department, conducting the work under his charge in a business-like manner and in successfully completing extensive harbor improvements within his original estimate. It is but fair to state, however, that a large proportion of the best engineers of the corps condemn the whole proceedings as an outrage, and state that if such a verdict can be found on the kind of evidence submitted by the prosecution in this case no self-respecting engineer in the Government service is safe from persecution.

When we consider the treatment which has been accorded projects under the direction of civil engineers by this organization it is easy for them to view this state of affairs with considerable complacency.

The case, from beginning to end, has been so peculiar that even the President has been impelled to ask as to who is behind the prosecution. No charge was made that any of the officer's funds were missing; that any of his engineering accounts were irregular, or that the contractors were ever paid one penny more than called for under this contract.

The allegation as to embezzlement arose only from the fact that, technically, any money paid out for work not done strictly in accordance with the specifications, as interpreted by the department, is claimed to be embezzled, the contention of the prosecution being that, while the quantities paid for were those actually put in the work and the prices paid actually those of the contract, the specifications of the contract were improperly interpreted by the engineer and therefore the money was technically embezzled. It was developed at the trial that the specifications and contract were approved by the division engineer and chief engineer of the corps and by the Secretary of War, and that the lowest bid was recommended to the department for acceptance and was approved by the Chief of Engineers. The work had been advertised as required by law, and the sealed proposals were opened publicly on the specified day. It was contended, however, that the materials used, namely,

the brush fascines, mattresses and stone, were different in character from those called for in the specifications, and hence that the Government had been defrauded. This, however, was not proven by reliable evidence, but, on the contrary, it was shown by a number of the ablest officers of the corps and by civil engineers of wide experience that the work was not only in accordance with the specifications, as interpreted on a large number of other important works, but that had the specifications been interpreted as contended for by the prosecution the work would have cost the Government at least $1,000,000 more than the amount it was actually completed for. This work is the only example on the Atlantic Coast where extensive improvements have been completed within the original estimates, and yet the officer in charge has been tried for embezzling the entire amount expended on the project. In this connection it should be stated that there are but few important national improvement projects in the United States, whether completed or not, which have not cost largely in excess of the engineers' original estimates.

There is no legitimate excuse for such estimates, and it is sincerely to be hoped that the investigations in New York relative to the Erie Canal improvements will make such work sufficiently unpopular that less of it will be done in the future.

Civil engineer employes of the Engineer Corps have recently been placed under the control of the Civil Service Commission. There is no doubt that, so far as clerkships in the Post Office and other departments are concerned, the protection afforded by the Civil Service Act of 1883 has been of great benefit to that vast army of officials and also to the Government service, but since in engineering matters success depends largely on the principle of "survival of the fittest" the restriction of the Civil Service rules in regard to the selection and appointment of men qualified to best do the work required and to discharge assistants when found inefficient, together with the tendency to destroy ambition, cannot be otherwise than detrimental to the service. The very fact that a man knows that his tenure of office or promotion does not depend upon the amount or quality of the service he renders often makes him inefficient. Engineers like to take the world easy as well as men of other professions, and when this can be done without detriment to position it is likely to occur.

The engineer service has never been subject to the abuses arising from political appointments, which gave rise to the Civil Service Act, and consequently there was no excuse for placing the employes under its regulations. The Engineer Corps are entitled

to much credit for having at all times resisted every attempt to subject the department to the spoils system, and, having demonstrated their ability to do this, it seems strange that they should have allowed the organization to be loaded down with unnecessary and cumbersome methods.

It is just as easy to formulate rules to prevent all undue political influence in the management of public works as to make the positions of field and office engineers independent of the officer directly responsible for the success of the work, to have appointments to important positions made by officials wholly ignorant of the work and its requirements, and to make such officials the arbiters as to whether inefficient assistants should be discharged.

It is true that the regulations are evaded by allowing work under the charge of inefficient men to be discontinued, but this is no credit to the system, for if the rules are not such as can be squarely lived up to without detriment to the service they should be either modified or eliminated at once.

The Navy Department has recently established hydrographic offices at a number of our lake cities, and its officers are engaged in making surveys and in publishing and issuing charts without regard to the duplication of similar work being done under the direction of the Engineer Corps.

A system of national public works which admits of unseemly quarrels between departments as to which shall have charge of different works; which allows the discrediting of the work of one department by another and the duplication of work and consequent waste of public funds; which promulgates such rules and regulations for its guidance that the cost of doing work and of disbursing the funds appropriated for its use is largely in excess of what it should be; whose members are liable to be court-martialed and to have their reputations and fortunes wrecked for not complying with regulations which it is probable that every officer in the corps is compelled to violate in order not to subject important works under their charge to serious delays and loss; which admits of petty jealousies relative to any river or harbor work designed or executed by civil engineers, and which it has been the policy of the organization to wreck financially if possible, would seem to embody all of the conditions summarized in the distinguished Senator's statement that we have the worst system of national public works on the face of the earth.

A military education is by no means an essential qualification for a successful river and harbor engineer, neither is it just that the graduates of our colleges and universities should be restricted in

the practice of their profession by the Government assigning all national improvements to a body of men educated at public expense. It is true that civil engineers are now occasionally appointed on engineer boards and commissions, yet assistant engineers in the United States service, although often the best qualified for such positions, are seldom so promoted, and as the experience of most engineers, outside of those who have been in the Government service, has not been such as to qualify them for the duties to be performed on river and harbor work the army officers on such mixed commissions are in a position to control to a great extent the tenor of reports submitted.

If an attempt should again be made to reorganize the methods of conducting national public works no system should be considered which does not fully recognize the ability and attainments of the members of the present corps, among whom are many engineers who if not hampered by the cumbersome system under which they serve would no doubt achieve national reputations.

During the present year the number of officers of the Engineer Corps has been increased fifteen per cent. by Act of Congress, presumably for the reason that additional military engineers were needed in carrying on the war with Spain; but that reason now no longer exists, and, if our standing army is to be largely increased, why should not the graduates of West Point attend to the fortification work, for which they were educated, and not be given a monopoly of the engineering on public improvements when the experience and education of the civil engineers and the business methods of civil life are far better adapted for securing economy and success?

If the military duties of the corps have become such that it is necessary to largely increase the number of officers of that organization, it would seem proper that at the same time the rights of the civil engineer should be recognized, and that Congress should also reorganize the system of conducting national public works so that the best practical results may be obtained at minimum expense and the ablest engineers of the country, whether military or civil, secured for the Government service.

Association of Engineering Societies.

Vol. XXI. JULY, 1898. No. 1.

PROCEEDINGS.

Civil Engineers' Club of Cleveland.

THE regular meeting was held at Case Library, July 12. Present, seventeen members and four visitors. President Osborn in the chair. The minutes of the last meeting were read and approved.

Messrs. Boalt and Culley were appointed tellers to canvass the ballots received. They reported the election, to active membership, of Robert L. Webb and Francis Henry Treat.

There was no report from the Executive Board. The chairman of the Programme Committee was not prepared to announce the title of the paper for the next meeting.

Mr. Benjamin S. Hubbell, of the firm of Hubbell & Benes, delivered an address upon the subject of "Marble *versus* Granite."

He was led to this topic by a recent study of the various marbles and granites of this country, with reference to their adoption in the construction of the Wade Memorial Chapel and Receiving Vault now building at Lake View Cemetery. The present Mr. Wade thought that the white terra cotta which is much used of late would be a suitable material, but on further reflection this was discarded in favor of stone.

The design of the building has a row of columns along the side, behind which are plain walls to which terra cotta is not well adapted, since its surface is not perfectly true. Again, with terra cotta we should require metal beams in the lintels, veneered with this material. It is true that had the building been designed in metal and terra cotta the metal columns would have cost only $60, while the marble columns would have cost $800 apiece. Nevertheless, for the sake of sincerity and good taste marble was the material selected, and it was proposed to use white marble, but we soon discovered that all white marble is not white.

Mr. Norcross recommended the Georgia marble, and so did Mr. Tiffany. This has been used in building the State Capitol at Providence and the Corcoran Gallery, Washington. The only building we know of which is really white is the Mausoleum at Detroit. This is built of Rutland marble.

The surface of marble soon disintegrates in the climate of Cleveland, and becomes granular as well as discolored. Old tombstones in the city graveyards show this, and would hardly be recognized now as marble. However, a protective fluid may be used with which new marble may be saturated, so as to become weather-proof and thoroughly durable.

We found South Dover and Tuckahoe marbles used in New York City. The Lee marble is largely used in Washington and Philadelphia, but this acquires a bluish gray tinge and the Tuckahoe turns brown. It has certain defects called "shakes," and contains some particles of magnesia, which dissolve in wet weather and leave the surface pock-marked.

The Vermont marbles were examined in the quarries and in buildings. No old marble was found in New York City that is not more or less discolored and disintegrated. The top surfaces are both rough and dark, while the under sides of projections are in good order. The Vermont quarries are probably the largest marble quarries in the world. These are at Proctor and East Rutland. The buildings of the Quarry Company are built of marble taken at random without selection. They are therefore quite mixed in color and give a really fine architectural effect. The owners were quite surprised at our admiration of these buildings.

The quarries have been excavated to a depth of 150 feet, crossing the beds of marble, which lie at a steep angle, and then have been tunnelled horizontally to cross the beds again. Several beds are found superimposed. It is seldom that a bed is more than thirty inches thick. The blocks are sawed into slabs regardless of the original bed, but so as to leave a white face, if possible. The marble in the same vein will be partly white and partly colored. The so-called fancy marbles all come out of the same quarry—red, white, black and blue—and sometimes even out of the same piece. The whole plant of these quarries is very fine. The Rutland marble is easily cut into fine lines and ornamental figures. On the other hand, Georgia marble is hard to cut, and unless great care is used large crystals will break out in cutting.

The Building Committee advised the use of granite, but the architects desired to use marble protected, which would be more beautiful and susceptible of elegant ornamentation, and would last a long time. But Mr. Wade said he wanted a building that would last five hundred years, therefore the idea of marble had to be abandoned.

Many samples of granite were sent to the architects. Granite is refractory and has to be tooled by hard and patient labor. Pneumatic tools have been invented for undercutting, but plain surfaces are generally worked by hand. Granite does not lend itself to fine ornamental lines and its gray color prevents the best effects of light and shadow.

Of course, it was necessary to change the ornamental design of the building to suit the change in material and arrange for heavier blocks in the walls. Marble can be used as veneering. It can be sawed as thin as five-eighths of an inch, but granite must be in blocks.

The granite found in the Barre Quarries occurs in layers separated by parallel seams through which water trickles. The stone next the seam is consequently saturated, and is called the sap. The sap is rejected in building, requiring a dressing off of the blocks of two or three inches from each bed. Usually granite blocks are split apart, though some sawing is done with chilled shot. At these quarries rotating disks are used to dress granite surfaces. The stone is first roughly pointed by hand and then run under the machine, which dresses off the surface to an absolute plane. This result is seldom obtained in hand work. In hand dressing a "number ten cut" (which means ten bits in 5/8 of an inch) is about the best, but more

depends on the skill of the laborer than upon the number of bits to the inch.

Of all the granites, the North Jay seems to have the lightest color. Grant's tomb and the new Bowling Green, New York, are built of this. It is, however, rather porous and soft and occasionally discolored by iron. A few defective blocks may spoil the effect of an entire building. Westerly granite is the darkest of all. The Concord granite is used in the Congressional Library Building at Washington. It contains some particles of magnesia. The Troy, N. H., granite is light and sound and of good quality. It forms the steps of the Congressional Library. The Halliwell granite was used in building the State Capitol at Albany. Barre has the most prolific quarries in America, but the product is liable to have iron in it, at least in the sap. Small specks of iron, hardly detected in the first instance, will later dissolve and streak the whole surface. However, it has been used for twenty-five years, and some monuments built of it are still as good as new. Many fine specimens of this granite may be seen in Lake View Cemetery.

The Halliwell granite is the best and most expensive, and is largely used for monumental work. It is homogeneous, all sections presenting the same appearance in whatever direction they are taken.

It was finally decided to use either the Troy or the Barre granite in the Memorial Chapel.

In conclusion, Mr. Hubbell stated that although Mr. Wade was recommended by friends to go to New York, or even to Europe, to select his architect, he nevertheless decided that this building should be designed and constructed by Cleveland architects.

The speaker exhibited various samples of marble and granite, illustrating the effect of shade and color. Many of these were very handsome and were examined with great interest. There was one sample of white Italian marble which had been exposed to the Cleveland climate for years, till its surface was black, and it had so far disintegrated that it could be crumbled between the thumb and finger.

A discussion ensued in which Messrs. Barnum, Hopkinson, Boalt, Searles and Benes participated.

On motion of Mr. Hopkinson, a vote of thanks was tendered Mr. Hubbell for his interesting and instructive address.

At 10 o'clock the Club adjourned and luncheon was served.

Boston Society of Civil Engineers.

Boston, June 15, 1898.—A regular meeting of the Boston Society of Civil Engineers was held in Lorimer Hall, Tremont Temple, at 8 o'clock p.m.; President Howard A. Carson in the chair; fifty-two members and visitors present.

The record of the last meeting was read and approved.

Messrs. John A. Holmes and Eugene C. Hultman were elected members of the Society.

The Secretary read a letter from Mr. Clemens Herschel, member of the Society, offering to present to the Society a piece of ancient Roman pipe on condition that the Society would undertake to properly mount it and preserve it. On motion of Professor Allen, it was voted: That the Secretary be authorized to inform Mr. Herschel that it would give the Society

great pleasure to receive the section of ancient Roman pipe, and the Society will mount it, place it in the library and adopt reasonable precautions for its safety.

The President announced that the 3d of July will be the fiftieth anniversary of the organization of the Society, and suggested that the event should be observed in a fitting manner. The Board of Government had considered the matter, and inasmuch as the exact anniversary occurred on Sunday, it recommended that the celebration be held early in October, next, and that it take the form of a social gathering, at which an historical address should be delivered, and other appropriate exercises held. On motion of Mr. G. A. Kimball, it was voted: That the Society approve the measure and method of celebrating the semi-centennial anniversary of the organization of the Society, as outlined by the President, and that the arrangement of the details of said celebration be referred to the Board of Government with full powers.

Mr. A. U. Jaastad, of Boston, was then introduced, and read a paper entitled, "Modern Steam Plants for Electric Railways." At the conclusion of the reading of the paper the thanks of the Society were voted to Mr. Jaastad for his interesting paper.

Mr. Gilbert Hodges followed with a paper entitled, "Story of the Street Railway."

Adjourned.

S. E. Tinkham, *Secretary.*

Association of Engineering Societies.

Vol. XXI. AUGUST, 1898. No. 2.

PROCEEDINGS.

Civil Engineers' Club of Cleveland.

Cleveland, August 9, 1898.—The regular meeting was called to order at 8 o'clock by President Osborn. Present, fifteen members and five visitors. The minutes of the last meeting were read and approved.

The Secretary reported for the Executive Board a balance of over $140 in the Library Fund, and invited suggestions as to new books suitable to be purchased for the library.

There being no other business, Mr. Lehman B. Hoit, member of the Club, then read a paper on "Test Meters for Steam Boilers," and also gave some notes upon "Steam Accumulators" and exhibited a working model of a water meter.

The topics were discussed by Messrs. Palmer, Roberts, Porter, Herman and others.

A social hour followed adjournment, and refreshments were served.

Wm. H. Searles, *Secretary.*

ASSOCIATION OF ENGINEERING SOCIETIES
Longitude West from Greenwich
CANADA
MEXICO
GULF OF MEXICO
PACIFIC OCEAN
ATLANTIC OCEAN
MONTANA
MINNEAPOLIS
ST. PAUL
DETROIT
BUFFALO
CLEVELAND
BOSTON
Philadelphia
VIRGINIA
ST LOUIS
DENVER
PACIFIC COAST
WASH.
ORE.
CAL.
IDAHO
NEV.
UTAH
ARIZ.
MONT.
WYO.
COLO.
N. MEX.
N. DAK.
S. DAK.
NEBR.
KAN.
OKLA.
IND. TY.
TEX
MINN.
IOWA
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ARK.
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ILL.
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OHIO
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// Association of Engineering Societies.

Vol. XXI. SEPTEMBER, 1898. No. 3.

PROCEEDINGS.

Technical Society of the Pacific Coast.

Regular Meeting, August 6, 1898.—An excursion to Mt. Tamalpais and an informal meeting there having been planned by the directors, the members of the Society, accompanied by their ladies, met at the ferry station and crossed the bay on the 9.30 A.M. Sausalito steamer. The ascent of the train to the summit of the mountain was enjoyed by all.

After luncheon at the Mountain Tavern, the meeting was called to order by Vice-President Percy, whereupon Mr. W. H. Hammon and Mr. McAdie, of the United States Weather Bureau, addressed the members on the subject of scientific kite flying, explaining in detail the principles and the construction of a modern kite and the results that may be achieved through their use in meteorological science. A discussion followed, carried on by Colonel Mendell, Mr. John Richards and others.

A rising vote was tendered to the authors for their interesting paper.

The meeting then adjourned, and the party returned to San Francisco on the 4.20 P.M. train.

Otto von Geldern, *Secretary.*

Regular Meeting, September 2, 1898.—Called to order at 8.30 P.M. by President Molera.

The minutes of the last two previous meetings were read and approved.

Mr. G. W. Percy read a paper, entitled "Roman Construction," which was discussed by many members and visiting architects.

Adjourned.

Otto von Geldern, *Secretary.*

Engineers' Club of St. Louis.

475th Meeting, September 21, 1898.—The meeting was held at 1600 Lucas Place, at 8 P.M., with President Bryan in the chair. Nineteen members and seven visitors were present.

The President addressed the Club, stating that as the meeting was in memory of the late Colonel Flad, all routine business would be dispensed with. He stated that the engineer seldom accumulates wealth, and that communities seldom erect monuments to his memory, but that his monu-

ments consist in the structures which are erected by him and in the esteem of his fellow-engineers. He referred to the close connection of Colonel Flad with the Engineers' Club of St. Louis, and introduced Mr. Robert Moore as the principal speaker of the evening.

Mr. Moore began with a biographical sketch of Colonel Flad, stating that he was born in the Grand Duchy of Baden in 1824, was educated at the University of Munich, entered the government engineering corps, and came to this country in 1849 on account of his participation in the parliamentary war of 1848. He was engaged in the construction of the New York and Erie Railroad, the Ohio and Mississippi Railroad and the Iron Mountain Railroad. When the war broke out he was appointed captain and afterwards colonel of engineers. After the war he returned to St. Louis, and was a member of the Board of Water Commissioners until 1875. He was also principal assistant engineer during the construction of the Eads Bridge. He was president of the Engineers' Club of St. Louis for twelve consecutive years, from 1878 to 1890. He was president of the Board of Public Improvements from 1876 to 1890, and a member of the Mississippi River Commission from 1890 until his death in 1898. The distinguishing characteristics of Colonel Flad were his wonderful fertility of invention and his high standard of honesty.

The Club was then addressed by Dr. C. M. Woodward, Mr. Julius Pitzman, Prof. J. B. Johnson, Mr. B. H. Colby and Mr. Albert Borden, each of whom treated of some event in the life of Colonel Flad or some phase of his character.

The Club then adjourned to the library, where lunch was served.

Richard McCulloch, *Secretary.*

Civil Engineers' Club of Cleveland.

Cleveland, September 13, 1898.—The regular monthly meeting was held in Case Library, September 13, at 8 p.m. Both presiding officers being absent, Mr. W. R. Warner was chosen President *pro tem.* Present, twenty-two members and five visitors.

The minutes of the last meeting were read and approved. There was no report from the Executive Board, no session having been held for lack of quorum.

Mr. St. John reported that the Program Committee had provided for all coming meetings this year, but gave no particulars.

The proposed amendment to the Constitution, changing the name of the Club, was then taken up and discussed. Remarks were made by Messrs. Hyde, Miller, Oldham, Baker, Porter, Searles, Mordecai and Prof. Benjamin. The question being put on Mr. Swasey's amendment, viz., that this Club be called "The Cleveland Society of Civil Engineers," was lost by a large majority. The question recurring to the original proposition as signed by the petitioners, viz., "The name of this Association shall be 'The Cleveland Society of Engineers,'" was discussed by Messrs. Coffin, Mordecai, Palmer, W. B. Cowles, Hyde, Baker and St. John. Mr. St. John, seconded by Mr. Skeels, moved to amend by substituting the title "The Cleveland Technical Society." This was put to question and lost.

Mr. Mordecai moved the postponement of further discussion of the main question to the next regular meeting. Carried.

Mr. J. P. Coffin then read a paper on "Some Points of Interest Gathered from an Inspection of the Machinery of Vessels on the Great Lakes, Together with a Synopsis of the Rules Compiled by the Great Lakes Register for Future Construction, and the Reasons for the Same," which was listened to with great attention. The paper reported upon the prevailing types of boilers, engines, pumps and other machinery now afloat on the Great Lakes, as ascertained from a critical survey of over 1300 vessels; it mentioned certain defects in design and proportion, and described the rules adopted to govern future construction. The subject was discussed by Messrs. Oldham and Miller, and at 10 o'clock the Club adjourned and refreshments were served.

Wm. H. Searles, *Secretary.*

Detroit Engineering Society.

The regular monthly meeting was held at the Hotel Ste. Claire, Friday evening, September 23; Vice-President W. J. Keep presiding, with twenty-four members and seven visitors present.

The Executive Committee reporting favorably upon the following applications, the candidates were elected to membership: L. C. Sabin, U. S. Asst. Eng., Port Huron, non-resident; S. H. Woodard, Asst. Eng., Deep Waterways Commission, resident; H. S. Bissell, Supt. Page Wire Fence Co., Walkerville, Ont., resident.

A communication from the American Society of Civil Engineers, containing resolutions of thanks for assistance in connection with the Thirtieth Annual Convention, was read and placed on file.

Messrs. Walter F. Beyer and John R. Allen were proposed for membership and referred to the Executive Committee.

The Secretary presented his resignation, to take effect October 1, 1898, which was accepted; and upon the nomination of the Executive Committee, Mr. Henry Goldmark was confirmed as his successor.

The paper of the evening, "Sanitary Engineering in Detroit," was presented by Mr. A. B. Raymond, Sanitary Engineer to the Board of Health, and was discussed by Messrs. Dow, Goldmark, Keep, Williams, Woodard, Molitor and the author.

Adjourned.

Gardner S. Williams, *Secretary.*

Meeting of the Executive Committee, held at 57 E. Hancock avenue, September 22, 1898. Present, Messrs. Keep, Dow, Russel, Smith, Hinchman and Williams.

Candidates for membership proposed at the last meeting were unanimously endorsed.

The Secretary announced his resignation, and Mr. Henry Goldmark was unanimously nominated to succeed him.

Bills of Spitzley Bros., for blackboard, amounting to $6.25, and of Richmond, Backer & Co., for printing, etc., amounting to $8.45, were approved and ordered paid.

Gardner S. Williams, *Secretary.*

Association of Engineering Societies.

Vol. XXI. OCTOBER, 1898. No. 4.

PROCEEDINGS.

Engineers' Club of St. Louis.

476th Meeting, October 5, 1898.—The meeting was held at 1600 Lucas Place, at 8 p.m., with President Bryan in the chair. Sixteen members and two visitors were present. The minutes of the 474th and the 475th regular meetings and the 261st and 262d meetings of the Executive Committee were read and approved.

The Secretary announced that he had received applications for membership from Messrs. Denney W. Roper, Victor Henry Poss, Charles W. Chassaing, Alfred Boyd and Samuel Trepp.

The applications for membership of Messrs. Albert B. Hazzard and Lovell Henry Carr having been approved by the Executive Committee, these gentlemen were balloted for and elected members of the Club.

Prof. J. H. Kinealy moved that the Secretary address letters of thanks to the Wiggins Ferry Company and to Mr. Lemon Parker for courtesies extended to the Club during the summer. This motion was unanimously carried.

A letter was then read from Mr. Charles L. Bouton, who had been appointed a delegate from the Engineers' Club of St. Louis to the Fiftieth Anniversary Celebration of the Society of Civil Engineers of France.

The President stated that the Missouri Historical Society had invited the Club to participate in the arrangements for the celebration of the Louisiana Purchase.

The discussion of the smoke abatement movement in St. Louis was then taken up. Mr. Eugene McQuillan, the attorney of the Citizens' Smoke Abatement Association, addressed the Club in regard to the legal questions involved. He stated that an ordinance had been passed by the Municipal Assembly several years ago which prescribed a punishment for the emission of dense, black smoke. Several convictions had been secured under this ordinance and the smoke nuisance had been largely abated, until on an appeal case the Supreme Court of Missouri decided that the Municipal Assembly had exceeded its rights under the city charter in passing the ordinance. Mr. McQuillan stated that a new ordinance was in course of preparation and is soon to be introduced in the Municipal Assembly.

Remarks on the subject of Smoke Abatement were then made by Col. E. D. Meier, Messrs. Robert E. McMath, Robert Moore and M. L. Holman.

There being no further business, the Club adjourned to the library.

RICHARD MCCULLOCH, *Secretary.*

477TH MEETING, OCTOBER 19, 1898.—The meeting was held at 1600 Lucas Place, at 8 P.M., with President Bryan in the chair. Twenty-six members and nine visitors were present. The minutes of the 476th regular meeting and the 263d meeting of the Executive Committee were read and approved.

The Executive Committee having reported favorably upon the applications for membership of Messrs. Denney W. Roper, Victor H. Poss, Alfred Boyd, Charles W. Chassaing and Samuel Trepp, these gentlemen were balloted for and elected members of the Club.

Mr. S. Bent Russell moved that the members of the Board of Managers of the Association of Engineering Societies representing the Engineers' Club of St. Louis be instructed to bring before the Board of Managers the question of publishing annually in the JOURNAL a list of all the members of all the Clubs belonging to the Association. After some discussion, this motion was carried.

The paper of the evening, by Mr. B. H. Colby, was then read. It was entitled "Repairs to the Mill Creek Sewer." A sketch of the history of this sewer was given. Its section is twenty by fifteen feet and its present length is about 25,000 feet. The present dry weather flow is about 40,000,000 gallons. It was begun in 1860 and has been built by piecemeal. The sewer was originally built on a timber bottom and the weight of the side walls has forced up the timber under the center of the sewer. The timber is now being replaced by a concrete inverted arch and the methods employed to effect these repairs were described. A large number of lantern slides were used to illustrate the subject.

The paper was discussed by Messrs. Moore, Pitzman, Ockerson and Holman.

There being no further business, the meeting adjourned.

RICHARD MCCULLOCH, *Secretary.*

Boston Society of Civil Engineers.

BOSTON, SEPTEMBER 21, 1898.—A regular meeting of the Boston Society of Civil Engineers was held in Chipman Hall, Tremont Temple, at 8.15 o'clock P.M.; President Howard A. Carson in the chair; ninety-two members and visitors present.

The record of the last meeting was read and approved.

Messrs. Frank S. Bailey, Edward D. Sabine and Gilbert S. Vickery were elected members of the Society.

On motion of Professor Allen, the thanks of the Society were voted to the New England Gas and Coke Company, to Col. S. M. Mansfield, Engineer Corps, U. S. A., and to the Portland Stone Ware Company, for courtesies extended to the members of the Society on the occasion of the several excursions made during the past summer. The thanks of the Society were also voted to the American Street Railway Association for the compli-

mentary tickets admitting our members to the Association's exhibition recently held in Boston.

The Secretary read a letter from the Secretary of the Society for the Promotion of Engineering Education, conveying a vote of thanks from that Society for the courtesies shown its members by this Society in arranging excursions to points of engineering interest during the recent meeting in Boston.

The President announced that the semi-centennial celebration of the Society would take place early in November.

The literary exercises of the evening took the form of a talk by President Howard A. Carson on the proposed East Boston tunnel, illustrated by lantern views. Mr. Carson briefly reviewed the various methods of submarine tunneling, and spoke particularly of the method of placing tubes in dredged trenches as used in the tunnel under Shirley Gut for the Metropolitan Sewerage System. In the studies for the East Boston tunnel this method has been considered, but as yet no plan had been adopted. Mr. Carson also discussed the various routes which had been proposed and the plans for connecting the Boston end with the subway. Adjourned.

S. E. Tinkham, *Secretary.*

Boston, October 19, 1898.—A regular meeting of the Boston Society of Civil Engineers was held in Chipman Hall, Tremont Temple, at 7.50 o'clock p.m.; President Howard A. Carson in the chair; sixty-five members and visitors present.

The record of the last meeting was read and approved.

Messrs. John B. Blood, Harry G. Botsford and Homer R. Stanford were elected members of the Society.

Prof. Ira N. Hollis occupied the evening with an informal talk on "The Engineering Features of the Spanish War." Adjourned.

S. E. Tinkham, *Secretary.*

Civil Engineers' Club of Cleveland.

Cleveland, October 11, 1898.—The regular monthly meeting was held in Case Library at 8 p.m. President Osborn in the chair. Present, sixteen members and four visitors. The minutes of the last meeting were read and approved. There was no report from the Executive Board, no session having been held owing to the lack of a quorum.

A letter was read from Mr. John C. Trautwine, Jr., Secretary, addressed to the Club, urging the securing of advertisements for the Journal. On motion of Mr. Mordecai, the letter was referred to the Executive Board for action.

The discussion upon the proposed amendment to the constitution was resumed. Remarks were made by Messrs. Mordecai, Hyde, Gobeille, Oldham, Parmley and Dr. Langley. Mr. Parmley moved as an amendment, to strike out "The Cleveland Society of Engineers" and insert "The Cleveland Engineering Society." This was seconded by Dr. Langley and discussed by Messrs. Oldham and Hoit. The amendment was put to vote and received, ayes 9, noes 4, not voting 3; total 16. The amendment was declared adopted and the petition as amended was ordered to letter ballot.

Mr. Arthur A. Skeels, member of the Club, presented some "Notes and Observations on a Recent Trip Through Mexico." His description of the numerous cities which he visited was illustrated by a large number of fine photographs taken by himself. These views represented street scenes, cathedrals, towers, aqueducts, waterfalls, volcanoes, plantations, etc. He described Monterey as being a most ancient and foreign looking city, with houses of adobe. Its water supply is taken from local wells and its sanitation is exceedingly bad. It, however, enjoys electric lights, and street cars hauled by mules, tandem.

The Castle of Chapultepec, a very beautiful and imposing structure, is the official residence of President Diaz. At Tlaxcala is seen the tower of a church built by Cortez, the oldest in Mexico.

Some of the natural scenery is Swiss-like in its grandeur and beauty, particularly in the vicinity of Orizaba.

At Queretaro there is a long stone viaduct of considerable height carrying the water supply to the city, where beautiful fountains are constantly playing.

Guadalajara is the most beautiful town in Mexico; the theater and church are magnificent edifices and not far away are the Falls of Juanacatlan, the largest waterfalls in Mexico. These falls are utilized for power and the production of electric lights which are used in the city.

The lecture was highly enjoyed by those present. The Club then adjourned for luncheon.

WM. H. SEARLES, *Secretary.*

Louisiana Engineering Society.

NEW ORLEANS, OCTOBER 10, 1898.—The regular monthly meeting of the Louisiana Engineering Society was called to order this date at 8.10 P.M. by President Sidney F. Lewis, with fourteen members and two guests present. The minutes of the last meeting were read and approved; and, for the information of the members, the minutes of the meeting of the Board of Direction were also read.

The report of the Auditing Committee, submitting the statements of the Secretary and Treasurer which they had audited, was read and ordered filed. The Committee on an Excursion reported progress.

There being no other business, technical exercises were declared in order, and Mr. Coleman read a short paper seeking to open discussion on either one of four subjects,—viz., Bank Protection, Drainage, Sewerage, or the proposed construction and track rearrangement on Canal street, of which all the plans were submitted. Mr. Bell fully explained these plans, and read his report to the City Council on the subject. A discussion ensued which was participated in by Messrs. Harrod, Fox, Theard, Lombard, Tutwiler and Grandjean.

Upon motion by Mr. Fox, Mr. Coleman was tendered the thanks of the Society for his paper.

There being no further business, the meeting was adjourned at 9.40 P.M.

J. F. COLEMAN, *Secretary.*

Engineers' Society of Western New York.

At the September meeting of the Engineers' Society of Western New York Mr. H. L. Noyes read a very interesting paper on "The History of Bridges." At the October meeting Mr. T. Guilford Smith favored us with a paper on "Important Works in Egypt," which was extensively discussed.

From October 18 to 22, inclusive, we had the pleasure of entertaining the American Institute of Mining Engineers at their 75th meeting, held in Buffalo. Souvenir badges and descriptive pamphlets of information were distributed. A harbor excursion was given the visitors, as well as a reception at the Ellicott Club. At the introductory meeting the public library was open from top to bottom, thus offering the Academy of Natural Sciences, the Historical Society Rooms and Fine Arts Rooms and the library proper open to inspection, the officers of the several organizations being present to welcome the Institute members. One day was set apart for visiting the various manufacturing places of interest. The last day was spent at Niagara Falls. The local committee from our Society appointed to welcome the guests was composed of the following: W. C. Johnson, T. Guilford Smith, E. B. Guthrie, H. J. March, Carl Meyer, E. C. Lufkin, Geo. S. Hubbell, H. L. Noyes, Pemberton Smith and Mr. Shattuck. They all spent a great deal of time in perfecting arrangements, which were heartily appreciated by the Institute.

H. J. March, *Secretary.*

Technical Society of the Pacific Coast.

Regular Meeting, October 7, 1898.—Called to order at 8.30 p.m. by President Molera. The minutes of the last regular meeting were read and approved.

A letter was read from the Secretary of the Association of Engineering Societies, communicating a decision of the Board of Managers to allow the Societies a commission of 90 per cent. on any advertisement secured for the Journal, and suggesting the appointment of a committee from the Technical Society for the purpose of taking this matter under consideration and pushing it vigorously to a successful issue. Upon motion it was ordered that the Board of Directors be instructed to appoint a committee of three to investigate the possibility of securing suitable advertisements for the Journal, and to report thereon at an early convenience.

Mr. H. M. Kebby read a paper descriptive of an instrument called the "Econometer," a mechanical contrivance for weighing the percentage of carbonic acid developed during combustion. The paper was discussed at length, after which the meeting adjourned.

Otto von Geldern, *Secretary.*

Association of Engineering Societies.

Vol. XXI. **NOVEMBER, 1898.** No. 5.

PROCEEDINGS.

Engineers' Club of St. Louis.

478th Meeting, November 2, 1898.—The meeting was held at 1600 Lucas Place at 8 P.M., with President Bryan in the chair. Twenty-seven members and four visitors were present. The minutes of the 477th regular meeting and the 264th meeting of the Executive Committee were read and approved.

The Secretary announced that he had received an application for membership from Mr. Mark Bary, assistant in the office of Bryan & Humphrey.

Capt. F. H. Macklind gave an address upon "Roads and Roadways." He pointed out the necessity of good roads to our present civilization and showed how city streets had developed from country roads. A brief history was given of the street making and paving which had been done in St. Louis. The value of various pavements from different standpoints was discussed, and the paper closed by giving the methods used and the cost of cleaning the streets in different cities. A discussion of this subject followed, participated in by Messrs. Bouton and McCulloch.

Prof. Kinealy then exhibited a machine for boring triangular, square, pentagonal, hexagonal and octagonal holes. The machine can be used in connection with any drill press and bores the hole at one operation in about twice the time taken to bore a round hole. The inventor of the machine was introduced to the club and explained the manner of operating the drill.

An informal discussion followed, after which the Club adjourned.

Richard McCulloch, *Secretary.*

479th Meeting, November 16, 1898.—Meeting was called to order at 8.15 P.M.; President Bryan in the chair. Thirty-two members and thirteen visitors were present. On explanation by the chair that at this meeting it has always been customary to appoint a committee on nominations for officers for the ensuing year, Mr. Colby moved that a nominating committee of five be appointed by the chair. The motion was seconded and unanimously adopted. The chair announced the receipt of a report of the Massachusetts Board of Health and a report of the Missouri Geological Survey.

Prof. J. B. Johnson then presented his paper entitled "The Engineer as the Guardian of Public Health." The paper was brought out mainly by

the recent development of the new theory of infectious diseases, whereby the engineering field has been greatly widened. The paper dealt with the various means by which the injurious bacteria found their way into the human system, and stated that it is very largely the scope of the engineer to supply means of prevention of such infection, such as the proper building and cleaning of streets, removal of sewerage and the supplying of pure drinking water. Some interesting statistics were given showing the decrease in the death rate due to typhoid fever, which was brought about by changes in source of supply and by filtration, and comparisons were made with German statistics, in which country the filtration of water supplies is almost universal. The universal adoption of sand filters in this country was urged as necessary to the preservation of public health, but notwithstanding the great progress in Germany but little advance has been made here. It is unquestionably true that municipalities can be held liable for the results of the furnishing of impure water.

As engineers understand causes of disease as well as the methods of prevention, it is their duty to form and lead public opinion, in providing safeguards to preserve the public health.

The writer traced some of the unsanitary arrangements of our residences and criticised slightly some defects of our sewer system. As we are provided with surface water from the Mississippi River, itself a great natural sewer, and as we are soon to have the sewage from a great city turned into this river, it will be an absolute necessity to provide a filtration plant for our water supply. The paper concluded with a brief statement of the duties of engineers in the preservation of public health and happiness.

The discussion, participated in by Messrs. Colby, Moore, Johnson and Dr. Ravold, was very interesting.

The President announced as the Committee on Nominations Messrs. Ockerson, Russell, Holman, Herman and Layman.

On motion the meeting adjourned.

E. R. Fish, *Secretary pro tem.*

Detroit Engineering Society.

The 33d Regular Meeting was held at the Hotel Ste. Claire, October 21, 8 p.m.; Mr. W. J. Keep, First Vice-President, presiding. There were twenty members and guests present. Mr. J. R. Allen, University of Michigan, Ann Arbor, and Mr. Walter F. Beyer, U. S. Engineer Office, Detroit, were elected to membership.

On motion of Mr. Pope, the President was instructed to appoint a committee of three to draw up suitable resolutions commemorative of the valuable work done by Mr. G. S. Williams, late Secretary of the Society, in forwarding its interests and advancing its prosperity. The motion was discussed by Prof. Greene and Messrs. Dow, Mattson and W. S. Russel. Messrs. Greene, Wisner and W. S. Russel were appointed as members of the committee.

The paper of the evening, "Coal-Handling Machinery," was then read by the author, Mr. C. W. Russell.

It was discussed by Messrs. Dow and C. W. Russell.

Adjourned.

Meeting of Executive Committee, held October 21, 1898.—Present: Messrs. Keep, Hinchman, Pope and the Secretary.

The bill of G. S. Williams, Secretary, for stationery and postage was approved and ordered paid.

On motion of Mr. Pope, the Secretary was instructed to arrange for the printing of a new edition of the Constitution and list of members.

The resignations of Messrs. H. R. King and I. G. Sowter were accepted.

Mr. J. A. Mayers was proposed as a member by Mr. J. F. Lewis.

Adjourned.

The 34th Regular Meeting of the Society was held at the Hotel Ste. Claire, November 25, 1898, 8 p.m.; Mr. Geo. Y. Wisner, President, in the chair. There were thirty-five members and guests present.

On ballot, Mr. J. A. Mayers, of Detroit, was elected a member of the Society.

Prof. Chas. E. Greene, as chairman of the committee appointed at the last meeting, presented resolutions expressing the appreciation of the Society of the work done by Mr. G. S. Williams as Secretary. On motion, it was voted that the resolutions be printed in the Journal and a properly engrossed copy be sent to Mr. Williams.

The paper of the evening, "Experiences in the Engine Room of the U. S. S. Yosemite," was then read by the author, Mr. T. H. Hinchman, Jr. It was discussed by Messrs. Campau, Dow, Mattson and the author.

Adjourned.

Meeting of the Executive Committee, held November 25, 1898.—Present: Messrs. Wisner, Pope, Dow, Keep, Hinchman and the Secretary.

The application of Mr. J. A. Mayers for membership was approved and a ballot ordered to be taken at the next meeting of the Society.

Mr. Chas. O. Cook, a member of the Society, was, on his request, granted a transfer to the Cleveland Engineers' Club.

A letter was read from Mr. E. R. Stoddard, Secretary of a Joint Committee of the several Associations of Detroit Stationary Engineers, inviting the Society to co-operate in drafting a new ordinance with regard to the inspection of steam boilers in the city of Detroit. The judgment of the members was adverse to the proposed action, and the Secretary was instructed to inform the writer of the communication to that effect.

Adjourned.

Henry Goldmark, *Secretary.*

Resolutions adopted by the Detroit Engineering Society, November 25, 1898, appreciative of the work done by Mr. G. S. Williams as Secretary of the Society:

The members of the Detroit Engineering Society regret that the appointment of Mr. Gardner S. Williams to the Chair of Experimental Hydraulics at Cornell University has obliged him to resign the office of Secretary and to give up active participation in the affairs of the Society.

Its organization was due, in a very large measure, to Mr. Williams' earnest efforts, and his careful attention to all details has greatly furthered

its development. The Society desires to put on record its sincere appreciation of the deep interest which he has always shown in its work.

As engineer to the Detroit Water Board, Mr. Williams has proved not only that he is a skillful civil and hydraulic engineer, but also that he is remarkably well fitted to carry on research and experiments that require great care and accuracy. Results already obtained by him promise to throw much light on obscure hydraulic phenomena.

While the Society regrets to part with Mr. Williams, it rejoices that the academic position to which he has been called will open to him such a large and congenial field for investigation; and it anticipates the satisfaction of sharing with the profession at large in the results of hydraulic experiments conducted on a large scale with far better facilities than can often be commanded.

Signed,

Chas. E. Greene,
Geo. Y. Wisner,
Walter S. Russel,
Committee.

Louisiana Engineering Society.

New Orleans, November 5, 1898.—Despite the threatened inclemency of the weather some forty-two members and two hundred and fifty guests, including many ladies, met this day at noon, at the depot of the Spanish Fort Railroad, for the first "outing" of this Society. The party, after visiting the work being prosecuted near by on the drainage system, boarded a chartered train and visited other parts of the drainage system in course of construction, stopping at Pumping Stations 2 and 7, No. 2 being at Broad and St. Louis streets and No. 7 at the intersection of the Spanish Fort Railroad with the New Orleans and Western Railroad.

The Central Power Station was the next stopping point. The purpose of the system and the manner in which it is being carried out were explained here in a short address by Mr. Thos. L. Raymond, after which a lunch was partaken of. The party then proceeded to the Jourdan Avenue Pumping Station, which was in operation. This is the outermost station of the system.

After leaving this point the train carried us to Port Chalmette, where the terminal facilities were inspected, after which the entire party returned to the city at 5.45 p.m., having thoroughly enjoyed the outing.

J. F. Coleman, *Secretary.*

New Orleans, November 14, 1898.—The regular monthly meeting of the Louisiana Engineering Society was called to order this date at 8.10 p.m., at the rooms of the Society, by President Sidney F. Lewis, with twenty-two members and three guests present. The minutes of the last meeting were read and, upon motion, approved. For the information of the members, the minutes of the Board of Direction were also read. The Auditing Committee reported by transmitting the statements of the Treasurer and of the Secretary, which they had audited and found correct. These statements, which showed a balance in hand of $371.28, were ordered filed. The Outing Committee stated that a report on the outing would be submitted as soon as all the bills were in hand, which would probably be

at the December meeting. Incidentally, the President requested all members who proposed bringing in applications from their brother professionals for membership to try and have them in the Secretary's hands by December 1, so that the letter ballot could be issued at such time as would perfect membership by January 1, 1899.

Technical exercises being next in order, Mr. A. F. Woolley, Jr., read a paper on "The Rectification of Red and Atchafalaya Rivers," which was an exposition of all the plans that have been considered for that end and a statement of the work that has been done. It was listened to with interest, and discussed by Messrs. Harrod, Fox, Raymond and Coleman.

Upon motion, the thanks of the Society were tendered Mr. Woolley for his paper. Announcement was made that at the December meeting, on the 12th of that month, the paper would be by Mr. A. C. Bell, on "The History of Street Pavements in New Orleans."

Upon motion, the thanks of the Society were tendered to the National Contracting Company and to the New Orleans and Western Railroad Company for courtesies extended by them on the occasion of the outing.

There being no further business, the meeting was adjourned.

J. F. Coleman, *Secretary.*

Civil Engineers' Society of St. Paul.

St. Paul, Minn., November 23, 1898.—The members of the Minneapolis Engineers' Club and others to the number of twenty-one, on invitation of the Civil Engineers' Society of St. Paul, met eleven of our members at 3 p.m. on the Selby Avenue Hill to inspect the working of the car-raising device under the direction of Mr. David Curtin. At 4.30 p.m. President Estabrook called the party to order in Parlor B, Hotel Windsor, where Mr. Curtin explained the drawings and distributed them for examination. At 5.30 the members of our Society withdrew to an adjoining room long enough to elect Mr. C. A. Winslow Treasurer *pro tem.* All were then assembled in Parlor B to listen to remarks by Prof. Hoag, Mr. Crosby and others. Supper was announced at 6 p.m. This finished, the company returned to the parlor to smoke, resolve and pass an indefinite time socially. Mr. Crosby introduced the following resolution, which was passed:

Whereas, we have this day examined the Bronsdon counterbalance on the Selby Avenue Hill, which has been operated during the past three months for a distance of 1000 feet; 500 feet on a 16 per cent. grade, thence about 200 feet on a curve and continuing to foot of lighter grade.

Resolved, That in our opinion the installation of this device is thorough and durable in character. The iron and steel work seems well proportioned with abundance of material in the various parts and the workmanship is apparently good.

Resolved further, That the Twin City Rapid Transit Company is to be commended for its effort to provide the public safe passage over this formidable ascent by means of a device which gives every indication of continued success.

Mr. Wilson, seconded by Mr. Howe, offered the following:

Resolved, That the members of the Civil Engineers' Society of St. Paul and the Minneapolis Engineers' Club hereby extend their thanks to the officers of the Twin City Rapid Transit Company for the opportunity of

examining the Bronsdon counterweight device in operation on the Selby Avenue Hill, and for the special facilities afforded for that purpose.

President Cappelen, on behalf of the Minneapolis Club, closed the business of the evening by inviting the St. Paul Society to visit the Beet Sugar Plant at St. Louis Park the coming month.

C. L. Annan, *Secretary.*

Technical Society of the Pacific Coast.

Regular Meeting, November 4, 1898.—Called to order at 8.30 p.m. by Professor Chas. D. Marx. The minutes of the last regular meeting were read and approved.

Mr. D. C. Henny read a paper, entitled "Wooden Stave Pipe in Comparison with Riveted Steel Pipe, with particular reference to the proposed Coolgardie Pipe Line." A discussion of the same subject was submitted by Mr. C. E. Grunsky and read by the Secretary. A long and interesting discussion then followed, in which many of the members present participated. Particular reference was made to the velocities obtained by the use of the Chezy and Kutter formulæ, differing opinions being expressed as to the reliability of these aids for pipes of larger diameter. Professor L. M. Hoskins discussed this particular feature, referring to experiments on the flow of water in the six-foot steel and wood pipe line of the Pioneer Electric Power Company, at Ogden, Utah, made by Professors Marx, Wing and Hoskins, in August, 1897. Upon motion a vote of thanks was passed for the author of the interesting paper.

Meeting adjourned.

Otto von Geldern, *Secretary.*

Montana Society of Engineers.

The regular monthly meeting of the Society was held in its rooms in Helena, Montana, on October 8. Meeting called to order at 8 p.m.; Vice-President F. J. Smith in the chair.

The minutes of the last meeting were read and approved. The application for membership of Mr. William Braden was favorably considered and the Secretary instructed to send out the usual letter ballots.

Helena was selected as the place for holding the Twelfth Annual Meeting of the Society.

A committee on arrangements consisting of J. S. Keerl, of Helena, Elliott H. Wilson, of Butte, and John C. Patterson, of Great Falls, was appointed to arrange the program. Paul S. A. Bickel, of Helena, Benjamin Bond, of Dillon, and Frank M. Leonard, of Libby, were appointed a committee to nominate officers for the ensuing year. A committee consisting of F. W. Blackford, John Herron and F. L. Sizer, appointed to draft a bill providing for a State Engineer and defining his duties, presented such a bill, which was accepted and the committee requested to again present the bill at the next meeting for discussion.

Votes of thanks were tendered to Messrs. Ellwood Mead, State Engineer of Wyoming, and Charles D. Walcott, director of the U. S. Geological Survey, for recent interesting and instructive lectures before the Society, and to the School Trustees for the use of the assembly room of the Helena High School on said occasions.

A. S. Hovey, *Secretary.*

Association of Engineering Societies.

Vol. XXI. DECEMBER, 1898. No. 6.

PROCEEDINGS.

Louisiana Engineering Society.

New Orleans, December 12, 1898.—The regular monthly meeting of the Louisiana Engineering Society was called to order this date at 8.05 P.M., by President Lewis, with twenty-seven members and six guests present. The minutes of the last meeting were read and approved.

The report of the Treasurer, which had been approved by the Auditing Committee, was read and referred to the Board of Direction.

There being no other business, technical exercises were declared in order, and an interesting and instructive paper was read by Mr. A. C. Bell on "The History of Street Paving in the City of New Orleans, and Discussion as to the Most Suitable Pavements for Traffic and other Correlative Conditions." At the conclusion of the paper, remarks were made by Mr. Grandjean on the maintenance of street pavements, or rather the lack of it in New Orleans; and Mr. Lombard spoke of the relative merits of gravel pavements here and elsewhere. Mr. Malochee, in discussing that part of Mr. Bell's paper which spoke of the necessity of a testing laboratory as an adjunct to the City Engineer's Office, expressed himself as being of the opinion that it is as great a necessity that the City Engineer's Department should be a permanent one, in which neither the head nor the subordinates could be disturbed by politics. He favored a permanent Board of Public Works, and finally moved that the administration of this Society shall submit a plan for such efforts on the next session of the Legislature, as will attain some such end, and will effect a more stable method of handling the Engineering Departments than now exists. This motion being duly seconded was passed. Mr. Lombard moved that the thanks of the Society be extended to Mr. Bell for his able paper. Carried unanimously.

Adjourned.

J. F. Coleman, *Secretary.*

Civil Engineers' Club of Cleveland.

Cleveland, O., December 13, 1898.—The regular monthly meeting was held in Case Library, December 13, at 8 P.M.; President Osborn in the chair. Present, twenty-one members and four visitors. The minutes of the last regular meeting were read and approved.

The President appointed Messrs. E. C. Cooke and J. W. Beardsley tellers to canvass the ballots received on applications for membership, and, on receiving the tellers' report, he announced that Walter Morrison Allen and Henry Martin Lucas were duly elected active members.

The Executive Board reported the applications of Chas. Olney Cook and Frederick Metcalf for active membership, and recommended them for letter ballot.

On motion of Mr. J. C. Beardsley, seconded by Mr. E. C. Cooke, the following resolutions were adopted:

Resolved, That a committee be appointed to investigate the feasibility of renting quarters for the Club in the new building of the Chamber of Commerce, and to report thereon at the next regular meeting.

Resolved, That the committee above mentioned be directed to confer with the Cleveland Architectural Club, Electric Club and Chemical Society with the view of securing their co-operation in the foregoing project.

The President appointed Messrs. J. C. Beardsley, W. R. Warner and Wm. B. Cowles to serve as such committee.

Mr. Edwin L. Thurston, associate member of the Club, read an instructive paper on "The Nature and History of Patent Rights." He defined the origin and limitation of the rights enjoyed by a holder of letters patent, showing them to be only such as the statute confers, and nothing by virtue of natural right or common law.

He discussed the two theories as to the nature of a patent right, the one regarding it as a monopoly, the other as a contract. The latter view has been generally adopted by the courts and by Congress in this country.

The author described the progress of patent law since the reign of James I., of England, in 1623, down to the present time. The first American patent statute went into effect April 10, 1790. Other patent laws were passed later, but in 1836 all preceding acts were repealed and the present system was inaugurated. A new law went into effect January 1, 1898, giving the patentee some additional advantages, and now more than fifteen bills are under consideration by the two Patent Committees of Congress. The paper closed with an apt quotation from one of the annual reports of the Commissioner of Patents.

An interesting discussion ensued between Messrs. Warner, Beardsley, N. P. Bowler, Palmer and Reed, and the author of the paper. The meeting adjourned at 9.30 and an hour was spent in conversation. Lunch was served.

Wm. H. Searles, *Secretary.*

Technical Society of the Pacific Coast.

Regular Meeting, December 2, 1898.—Called to order at 8.30 p.m. by Vice-President Percy. The minutes of the last regular meeting were read and approved.

A Nominating Committee to select a list of officers for the ensuing year was elected by the members present, as follows:

H. C. Behr, C. E. Grunsky, A. Lietz, Luther Wagoner and A. d'Erlach.

Mr. Marsden Manson, State Commissioner of Highways, delivered a lecture on "Roadway Construction in California," illustrated by stereopticon views of interesting localities and structures. A discussion followed. The

chairman thereupon announced the presence of five distinguished architects, who were called to San Francisco at the instigation of Mrs. Phœbe Hearst in connection with the competition for designs for university buildings at Berkeley. These gentlemen, Messrs. J. M. Hewlett and W. J. Lord, of New York; Professor D. Despradelle and Stephen Codman, of Boston, and E. Bauhain, of Paris, were then introduced to the members, who, after adjournment, repaired in a body to a neighboring café for social intercourse and conversation.

Otto von Geldern, *Secretary.*

Montana Society of Engineers.

The regular monthly meeting of the Society was held in its rooms in Helena, Montana, on November 12, 1898. Meeting called to order at 8 p.m.: Vice-President F. J. Smith in the chair.

The minutes of the last meeting were read and approved.

Messrs. Paul S. A. Bickel and L. S. Griswold were appointed tellers to canvass the votes for membership. The votes were all affirmative and Mr. William Braden was declared elected to membership. The bill providing for the appointment of a State Engineer, and defining his duties, was then read section by section and discussed, after which Mr. O. Jackson, recently from Alaska, addressed the Society upon railway, tramway and other improvements now being made in said country. Owing to a lack of time, the reading of the paper by F. W. Blackford, upon the Butte-Centerville Electric Railway, was postponed until the December meeting.

A. S. Hovey, *Secretary.*

Civil Engineers' Society of St. Paul.

St. Paul, Minn., December 5, 1898.—A regular meeting of the Civil Engineers' Society of St. Paul was held at 8.15 p.m.; President Estabrook in the chair and ten members present. Minutes of previous meeting read and approved. A letter from Secretary Trautwine urging the appointment of a local committee to solicit ads for the Journal of the Association was discussed without action as it was considered that the local circulation was insufficient to warrant local advertisements.

The Secretary was instructed to thank Superintendent I. F. Forbes, of the Great Northern Railway Company, and accept invitation to visit shops at some future time.

A revised membership list was ordered printed.

Mr. Charles A. Forbes was elected to membership.

Mr. Oliver Crosby read a paper on "The Manufacture of U. S. 12" Mortar Carriages."

The American Hoist and Derrick Company, of this city, have been turning out these carriages under his direction at the rate of two per month during the past year. He exhibited test pieces of gun iron, the strength of which must be twice that of ordinary cast iron.

After much experimenting in the mixture of various grades of iron he successfully melts, in a cupola furnace, the necessary twenty tons for one pouring, and moulds the same to pass the most rigid inspection.

C. L. Annan, *Secretary.*

Boston Society of Civil Engineers.

November 11, 1898.—A special meeting of the Boston Society of Civil Engineers was held at the Hotel Vendome, Boston, for the purpose of observing the semi-centennial anniversary of the organization of the Society.

There were present one hundred and seventy members and guests, including ladies.

A reception was held from 7.30 till 8 o'clock, the receiving party consisting of President and Mrs. Howard A. Carson, Vice-President and Mrs. C. Frank Allen and Vice-President and Mrs. Alexis H. French. The following members acting as ushers: Fred. V. Fuller, Henry D. Woods, Frank O. Whitney, Leonard Metcalf and Herbert L. Grew.

Soon after 8 o'clock President Carson called the meeting to order, and requested the Secretary to read so e of the communications which had been received from other engineering societies. In response the Secretary read a brief letter from Mr. Alphonse Fteley, President of the American Society of Civil Engineers, expressing his regrets at his inability to be present and conveying his congratulations upon the event which had brought the members together, and his best wishes for the future welfare of the Boston Society. Letters expressing similar sentiments were also received from the President of the Engineers' Club of St. Louis, from the President of the Civil Engineers' Club of Cleveland and from the President of the Detroit Engineering Society.

A cablegram was also read from the President of the Institution of Civil Engineers (London) offering "hearty congratulations to the Boston Society on their fiftieth anniversary."

A letter was read from the President of the Society of Civil Engineers of France alluding to the recent celebration by that Society of its semi-centennial and to the honor and pleasure it had in receiving a delegate from the Boston Society on that occasion. The letter named Mr. Henry D. Woods as a delegate to represent the Society of Civil Engineers of France at this meeting. The President called upon Mr. Woods, who in a very happy manner extended to the Society the congratulations of the French engineers and gave voice to the fraternal sentiments which unite the engineers of the two countries.

President Howard A. Carson then delivered the opening address and took for his subject "Glimpses of Boston Fifty Years Ago."*

At the conclusion of his address the President introduced Mr. Desmond FitzGerald, a Past-President of the Society, who reviewed its history in a very interesting address, tracing its existence from 1848 to the present time.†

The President congratulated the members upon having present on this occasion one of the founders of the Society, and introduced Mr. Samuel Nott, who took part in the first meeting of the Society, and was its Secretary from March 6, 1849, to August 7, 1874.

Mr. Nott expressed his great pleasure in being able to attend the anniversary exercises and gave a few reminiscences of the early days of the Society.

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*The address will be found on page 263 of this number of the Journal.

†The address will be found on page 268 of this number of the Journal.

At the conclusion of Mr. Nott's remarks the literary portion of the celebration closed.

A collation was then served, after which music and dancing concluded the program.

S. E. Tinkham, *Secretary.*

November 16, 1898.—A regular meeting of the Boston Society of Civil Engineers was held in Chipman Hall, Tremont Temple, at 8 P.M.; Vice-President Alexis H. French in the chair; eighty-six members and visitors present.

The record of the last meeting was read and approved.

Messrs. Byron I. Cook, Arthur C. Holt and Leonard L. Street were elected members of the Society.

The sum of $12 was appropriated to meet the incidental expenses of the semi-centennial celebration of the Society.

The thanks of the Society were voted to President Gilbert and other officers of the Boston Electric Light Company for courtesies shown the members of the Society who took part in the excursion to the works of that company this afternoon.

The thanks of the Society were also voted to Mr. J. H. Appleton, of the Riverside Paper Company, to Messrs. Chas. P. Deane and L. E. Bellows, of the Deane Steam Pump Company, to Messrs. E. S. Waters and J. M. Sickman, of the Holyoke Water Power Company, for courtesies shown the Society on the occasion of the visit to Holyoke, Mass., on October 21 and 22.

The Secretary read a letter from Mr. Levi R. Greene, member of the Society, presenting to the Society a portrait of the late Col. George E. Waring. It was voted to accept the gift, and the Secretary was directed to convey the thanks of the Society to the donor.

On motion of Mr. Brooks it was voted that a sum not exceeding $75 be appropriated for the printing of a souvenir pamphlet containing the addresses delivered at the semi-centennial celebration of the Society, provided the Board of Government deem such a publication desirable.

Mr. Stephen Childs then read a paper, entitled "The Maintenance of the System of Separate Sewers in Newton, Mass." A discussion followed on the maintenance of sewers in which Messrs. T. Howard Barnes, William Nelson, Otis F. Clapp and others took part. The Secretary read a short discussion on the same subject prepared by Mr. Bertram Brewer.

Adjourned.

S. E. Tinkham, *Secretary.*

Engineers' Club of St. Louis.

480th Meeting, December 7, 1898.—The meeting was called to order at 8.15 P.M.; with President Bryan in the chair. Thirty-four members and nineteen visitors were present. Sixteen of these visitors were ladies.

The minutes of the 479th regular meeting and the 265th meeting of the Executive Committee were read and approved.

The Secretary announced that he had received application for membership from Mr. William Fry Scott. The Executive Committee having reported favorably upon the application for membership of Mr. Mark Bary, this gentleman was balloted for and elected a member of the Club.

This being the annual meeting, reports were called for from the officers and standing committees. Reports were read from the following officers and committees: Secretary, Treasurer, Librarian, Board of Managers of the Association of Engineering Societies, Entertainment Committee and Executive Committee. The report of the Treasurer was referred to the Executive Committee for verification, and the other reports were ordered to be received and filed.

As the Committee on Standard Gauges for Thickness had no report to make, this committee was honorably discharged.

The Committee on Nominations reported the following nominations for officers for 1899:

For President—B. H. Colby.

For Vice-President—F. E. Nipher.

For Secretary—E. R. Fish.

For Treasurer—Thos. B. McMath.

For Librarian—E. J. Jolley.

For Directors—S. E. Freeman and J. H. Kinealy.

For members of the Board of Managers of the Journal of the Association of Engineering Societies—J. B. Johnson and Richard McCulloch.

On motion, the meeting was adjourned for five minutes to consider the report of the Committeee on Nominations.

When the meeting again convened, the following additional nominations were made:

For Vice-President—M. L. Holman, Ed. Flad and J. B. Johnson.

For Secretary—Henry Branch.

For Treasurer—E. H. Connor.

For Directors—A. H. Zeller and John A. Laird.

The President stated that in the absence of any objection, the Executive Committee would arrange for the annual supper to be held at the next meeting, December 21, 1898.

The paper of the evening, by Mr. A. H. Zeller, was then read. The author was a delegate from the Engineers' Club of St. Louis to the celebration of the Fiftieth Anniversary of the Civil Engineers of France, and the paper described the manner in which the event was celebrated. He gave an account of the excursions on which the visitors were taken and described the works of engineering interest which were visited. After the reading of the paper, a number of lantern slides were exhibited, showing views of engineering works in Paris, Berlin and other European cities.

A motion was made and carried that the Club make acknowledgment for the handsome manner in which its delegates were entertained, and that the thanks of the Club be extended to the delegates for their services in the celebration.

The Club then adjourned to the library, where refreshments were served and an informal reception held.

Richard McCulloch, *Secretary.*

481st Meeting, December 21, 1898.—The annual dinner was held at the Mercantile Club, at 8.15 o'clock. Forty-one members and eighteen visitors were present. After the dinner had been served, the meeting was called to order by President Bryan, who announced that the result of the letter ballot for officers for 1899 had been as follows:

President—B. H. Colby.
Secretary—E. R. Fish.
Treasurer—Thos. B. McMath.
Librarian—E. J. Jolley.
Directors—J. H. Kinealy and John A. Laird.

Members of the Board of Managers of the Association of Engineering Societies—J. B. Johnson and Richard McCulloch.

There was no one elected Vice-President, as none of the candidates had received a majority of the votes cast.

In the absence of the newly-elected President, Mr. B. H. Colby, Mr. Wm. H. Bryan retained the chair during the remainder of the evening.

The first toast on the program, "The Engineer of To-day," was discussed by Mr. Wm. H. Bryan. The speaker enumerated some of the difficulties which lie in the path of the engineer and pointed out the brilliant achievements of the master minds of the profession.

Col. E. J. Spencer spoke on "Our Late Unpleasantness." Col. Spencer gave a short sketch of the progress of the Cuban war, and paid a brilliant tribute to the patriotism of the American people. Taking into account the preparations which were necessary, and the scarcity of armament and supplies at the beginning of the war, the results were marvelous.

Mr. Richard McCulloch then responded to the toast, "Our Bachelors."

Prof. J. H. Kinealy spoke on the toast, "The Engineer in Mechanics." He stated that the study of mechanics is the basis of all engineering, and that when a student had mastered this subject, he had laid a firm foundation for future work.

The President then called upon Mr. Robert Moore to speak on "The Engineer as a Citizen." Mr. Moore warned engineers not to allow an interest in engineering to absorb their attention so completely as to prohibit them from performing the duties of a good citizen.

Informal remarks were made by Mr. M. L. Holman and Ex-Governor F. A. Tritle, of Arizona.

The meeting then adjourned.

Richard McCulloch, *Secretary.*

Detroit Engineering Society.

The 35th Regular Meeting of the Society was held at the Hotel Ste. Claire, Friday, December 16, 1898, at 8 p.m. Mr. G. Y. Wisner, President of the Society, was in the chair. A letter from the Executive Committee of the League of Associated Engineers with regard to indorsing H. R. Bell, No. 10,403, for reorganizing the personnel of the U. S. Navy, was read by the Secretary. No action was taken by the Society as a body.

The paper of the evening, "The Civil Engineer and National Public Works," was then read by the author, Mr. G. Y. Wisner, President of the Society. The subject was discussed in its various aspects by Messrs. Dow, Goldmark, Keep and Edward Molitor.

Adjourned.

Henry Goldmark, *Secretary.*

A Meeting of the Executive Committee was held at 34 Congress street, West, Friday, December 16, 1898. Present, Messrs. Wisner, Keep, Pope and Goldmark.

The following bills were approved and ordered paid:

Association of Engineering Societies	$22.75
Richmond & Backus Co., stationery	8.85
Henry Goldmark, Secretary, postage	1.50
Total	$33.10

It was voted that Mr. G. Y. Wisner's paper, entitled "The Civil Engineer and National Public Works," be printed in the JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES. The resignation of Mr. A. B. Atwater was accepted, to take effect at the end of the present fiscal year.

Mr. W. A. Livingstone having expressed a desire to retire from the position of representative of the Society on the Board of Managers of the Association of Engineering Societies, Mr. Gardner S. Williams was appointed in his place.

Adjourned.

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